OHEC
373.19109713
O59DE/C-S
Box 4

Ministry
of
Education
Ontario

Chris Ward, Minister
Bernard J. Shapiro, Deputy Minister

Curriculum Guideline

Science

Intermediate and Senior Divisions

1988

Part 14

Physics

Grade 12, Advanced Level, and the OAC

Contents

Introduction 3
The Parts of the Guideline 3
Policies and Features That Apply Across the Science Program 3
The Science Curriculum Continuum 5
Compulsory and Prerequisite Courses 5
Curriculum Emphases 5
Student Activities 5
Safety 6
Sensitive Issues 6
Locally Designed Units 6
Evaluation of Student Achievement 6
Cross References 6

Particular Features of the Senior Advanced-Level Physics Courses 7
Units of Study and Their Time Allocations 7
Interrelationships Between the Two Courses 7
The Grade 12 Physics Course 8
The Physics OAC 8
Metric Units in Senior Physics 9

Physics, Grade 12, Advanced Level (SPH4A) 11

Core Unit 1: Geometric Optics 12
Core Unit 2: Mechanics 16
Core Unit 3: Electricity 19
Core Unit 4: Electromagnetism 22
Core Unit 5: Sound 25
Core Unit 6: Nuclear Physics 28
Optional Unit 1: Astronomy 31
Optional Unit 2: Fluids 35
Optional Unit 3: Thermal Energy 38
Optional Unit 4: Locally Designed Unit 40

Physics, OAC (SPH0A) 41

Core Unit 1: Kinematics 42
Core Unit 2: Dynamics 44
Core Unit 3: Momentum and Energy 47
Core Unit 4: Electrostatics 49
Core Unit 5: Waves and Light 52
Core Unit 6: Early Quantum Theory 54
Optional Unit 1: Special Relativity 57
Optional Unit 2: Bodies in Equilibrium 59
Optional Unit 3: Electromagnetic Radiation 62
Optional Unit 4: Elementary Particles 64
Optional Unit 5: Locally Designed Unit 65

Appendixes 67

A. Science Courses and Their Course Codes 69
B. The Table of Contents of Part 1 70

Introduction

The Parts of the Guideline

This document is Part 14 of a fifteen-part curriculum guideline that outlines the science program for the Intermediate and Senior Divisions in Ontario schools and describes the science courses that can be offered (see the list of courses and their course codes in Appendix A). The term *guideline* refers to the entire set of fifteen parts.

This part must be read and implemented in conjunction with Part 1, *Program Outline and Policy*. When implementing the courses that are described in this document, teachers are to incorporate the many policies and features outlined in Part 1, which will enable them to interpret the overall intent and expectations of the Ministry of Education in the science program. The table of contents for Part 1 is given in Appendix B at the end of this document so that the reader may have ready access to the list of chapters and topics therein.

The provincial science program for the Intermediate and Senior Divisions comprises the courses described in Parts 2 to 15. These come under the framework and policy set forth in Part 1. The entire science guideline consists of the following fifteen parts:

Part 1: Program Outline and Policy
Part 2: Science, Grades 7 and 8
Part 3: Science, Grades 9 and 10, General Level
Part 4: Science, Grades 9 and 10, Advanced Level
Part 5: Science, Grades 9 and 10, Basic Level
Part 6: Science, Grades 11 and 12, Basic Level
Part 7: Environmental Science, Grades 10 to 12, General Level
Part 8: Environmental Science, Grades 10 and 12, Advanced Level
Part 9: Applied Biology and Applied Chemistry, Grade 11, General Level
Part 10: Applied Physics and Technological Science, Grade 12, General Level
Part 11: Geology, Grade 12, General and Advanced Levels
Part 12: Biology, Grade 11, Advanced Level, and the OAC
Part 13: Chemistry, Grade 11, Advanced Level, and the OAC
Part 14: Physics, Grade 12, Advanced Level, and the OAC
Part 15: Science in Society, OAC

The chart on the next page indicates the twenty-eight science guideline courses that may be offered in Grades 7 to 12 and at the OAC level.

Policies and Features That Apply Across the Science Program

Part 1 of the guideline specifies a great number of the policies and features that are to be integrated into the design of the science program in the Intermediate and Senior Divisions. There are too many of them to describe in full in each of Parts 2 to 15, but the following points will give the reader some idea of the scope that is involved. They include:

- information about the science credits that are required for the earning of the Ontario Secondary School Diploma;
- a list of science courses that are prerequisite to other science courses;
- the policy regarding mandatory student activities in the science laboratory;
- a list of the aims of the science curriculum and the various emphases that may be used to blend these aims with scientific content;
- policy governing time allocations for units of study and the order in which core and optional units may be taught;
- stipulations about locally designed units;
- suggestions about preferred routes that students might take through the science program in a secondary school;
- recommendations related to exceptional students, individualized instruction, life-management skills, career awareness, the role and evaluation of language in science courses, and a balanced perspective on the role of both girls and boys in science;
- recommendations on the introduction and handling of sensitive issues;
- specific suggestions about resources for the teaching of science;
- ideas about different modes of delivering science courses, including the co-operative education mode;

Authorized Science Guideline Courses, Intermediate and Senior Divisions

Grade 7	Science		
Grade 8	Science		
	Basic Level	**General Level**	**Advanced Level**
Grade 9	Science (SNC1B)	Science (SNC1G)	Science (SNC1A)
Grade 10	Science (SNC2B)	Science (SNC2G) Environmental Science (SEN2G)	Science (SNC2A) Environmental Science (SEN2A)
Grade 11	Science (SNC3B)	Applied Biology (SBA3G) Applied Chemistry (SCA3G) Environmental Science (SEN3G)	Biology (SBI3A) Chemistry (SCH3A)
Grade 12	Science (SNC4B)	Environmental Science (SEN4G) Geology (SGE4G) Applied Physics (SPA4G) Technological Science (STE4G)	Environmental Science (SEN4A) Geology (SGE4A)* Physics (SPH4A)
OACs			Biology (SBI0A) *Prerequisite* – Biology (SBI3A) Chemistry (SCH0A) *Prerequisite* – Chemistry (SCH3A) Physics (SPH0A) *Prerequisite* – Physics (SPH4A) Science in Society (SSO0A) *Prerequisite – One of:* Biology (SBI3A) Chemistry (SCH3A) Environmental Science (SEN4A) Geology (SGE4A)* Physics (SPH4A)

---

*Since the Grade 12 advanced-level geology course described in the guideline (see Part 11) may be taught under the aegis of a geography department as Geology (GGE4A) – note the course-code change – then either Geology (SGE4A) or Geology (GGE4A) may count as a prerequisite to Science in Society (SSO0A).

- policy pertaining to the significant role to be played by measurement and metric units in science courses;
- stipulations related to the treatment of symbols, significant digits, and mathematical problem solving;
- recommendations concerning the roles to be played by calculators and computers in science courses;
- specific directions about safety;
- policy and principles pertaining to the evaluation of student achievement;
- policy regarding differences in the treatment of science courses at the three levels of difficulty;
- many suggestions about implementing the science program.

It cannot be emphasized strongly enough that teachers of science must integrate the policy and recommendations outlined in Part 1 with the teaching of science and cannot simply rely on the course descriptions given in Parts 2 to 15 of the guideline.

The Science Curriculum Continuum

By the time students have reached the Senior Division they will have experienced first a *unified* approach in the Primary and Junior Divisions, in which science is related to a number of other subject areas, and then a *diversified* approach to a mosaic of science disciplines – biology, chemistry, physics, and environmental science – in the Intermediate Division. In the Senior Division they are provided with a *specialized* approach, in which the science courses deal with a single discipline at a time.

Although these approaches – unified, diversified, and specialized – provide different ways of dealing with the subject, the intention is to ensure that there is a continuum throughout the years. The two advanced-level courses in physics, the Grade 12 course and the OAC, build on the physical science units of the advanced-level courses in the Intermediate years. It is essential that students who wish to attend university and continue their study of physics include Grade 12 advanced-level physics and the physics OAC in their secondary school program.

Physics teachers should be aware of the subject matter contained in the physical science units of the Intermediate Division courses and of the way in which Senior physics, chemistry, and biology courses relate to one another.

In all science courses the core units and the prescribed number of optional units, if any, are to be included. The time allocation for each unit of study should act as a guide in helping teachers devote an appropriate amount of time to each of the units in a course. This is important in view of the continuum from one course to another and to postsecondary science programs.

Compulsory and Prerequisite Courses

In the secondary school program two science courses are required among the compulsory subjects that are necessary for the earning of the Ontario Secondary School Diploma. It is, therefore, anticipated that most of the students who enrol in Senior Division advanced-level physics courses will have taken Grade 9 and 10 science, also at the advanced level.

Physics, Grade 12, Advanced Level is a prerequisite to Physics, OAC. Principals may waive this requirement if a student has taken a course that may be considered to be equivalent to the prerequisite or if there is good reason to believe that the student can adequately cope with Physics, OAC in preparation for university.

Curriculum Emphases

It is recommended that teachers organize each of the courses described in this document around a particular curriculum emphasis or set of emphases. Such emphases give the curriculum a special focus that can be introduced in addition to the content and processes outlined in the courses. This approach is discussed in subsection 3.4, "Curriculum Emphases – Blending Curriculum Aims With Content", of Part 1 of the science guideline. A list of emphases is given in table 2 of that subsection. These emphases will enhance the development of the science courses described in this document. A particular emphasis that is stressed throughout an entire course or for one or more units at a time needs to be highlighted so that it becomes a focal or integrating theme.

Student Activities

In each unit of study there is a section entitled "Student Activities". This section indicates the *mandatory* laboratory activities required of students. Teachers may substitute *equivalent* laboratory activities where appropriate. Those activities that are actually to be performed by students themselves are marked with asterisks. If time and circumstances permit, the teacher should encourage students to do some or all of the unmarked activities as well. However, such activities may be demonstrated by a student or the teacher or may be discussed in conjunction with a textbook, film, computer program, or other learning material used as a resource. In any event, the scientific concepts and principles related to such unmarked activities and identified in the objectives of the unit of study shall be considered to be part of the prescribed course.

Generally, the best approach to the teaching of science is to ensure that the content develops directly from related student activities. In each unit of study the skills and processes of scientific work should usually be presented as the central component, from which the subject matter, applications, and implications emerge.

Safety

Safety awareness must be developed in all science students. Constant attention to accident prevention is to be stressed in all student activities and teacher demonstrations in the laboratory. Section 9, "Safety", in Part 1 of the science guideline contains the following comprehensive subsections:

- Safety in the Laboratory
- Some Recommended Safety Procedures
- Animal Care in Science Courses
- The Safe Use of Plants

In each unit of study, subsection 6, "Safety Considerations", acts as a reminder of some of the safety features that pertain to the unit in question. General reference, however, should constantly be made to the safety section in Part 1. Schools must always remain on the alert in regard to safety and maintain an up-to-date safety-awareness program.

Sensitive Issues

The curriculum outlined in this science guideline places a distinct emphasis on the science-technology-society connection. For this reason scientific applications and societal implications are mandatory components of each unit of study. In addition, Part 1 of the guideline underlines the need to incorporate morals/values education into science courses. Undoubtedly, this will give rise to the discussion of some sensitive issues.

Such discussions are important. Generally, they should be focused and should provide an open forum for the expression of different viewpoints. In this regard teachers of science are urged to familiarize themselves with section 10, "Values in Science Education", in Part 1 of the guideline and to pay particular attention to the principles to be observed when dealing with sensitive issues in the science curriculum. These principles are mentioned in subsection 10.2 of Part 1.

Locally Designed Units

Among the optional units in each of the courses described in this document is one entitled "Locally Designed Unit" (LDU). Such a unit is included to allow teachers, at their discretion, to introduce an appropriate new area of physics not described in the guideline, to expand on previous units or topics by adding new work, or, by using the time allocated to the LDU, to extend the time allocations for the core units. (See also Part 1, subsection 5.5.)

Evaluation of Student Achievement

Particular attention must be paid to the opening policy statements made in section 14, "Evaluation", in Part 1 of the guideline. The evaluation of student achievement in all Intermediate and Senior Division science courses must include certain components, as follows:

- laboratory activities and reports .... at least 15 per cent

and in addition for the OACs:

- independent study .... at least 10 per cent
- one or more formal examinations .... 30 to 40 per cent

In each unit of study described in the courses outlined in this document, subsection 5, "Evaluation of Student Achievement", specifies certain items that must be included in students' term marks (exclusive of formal examinations) when their achievement is evaluated. In most units teachers are required to evaluate students' activities and related laboratory reports. However, the proportion of the mark assigned will vary from one teacher to another. In order that the experimental component of science be emphasized, the overall mark for an entire science course must include at least 15 per cent for the evaluation of student achievement in laboratory skills and reports.

Cross References

In the descriptions of each unit of study in the courses outlined in this document, cross references are provided in parentheses. These are included to provide some examples of the relationships that exist among the parts of the unit.

Particular Features of the Senior Advanced-Level Physics Courses

Units of Study and Their Time Allocations

The following charts provide an overview of the units of study in the Grade 12 advanced-level course and the OAC. They also indicate the time to be allotted to each unit.

Physics, Grade 12, Advanced Level (SPH4A)

Units of Study		Time Allocations
Core		
1. Geometric Optics		16 h
2. Mechanics		25 h
3. Electricity		19 h
4. Electromagnetism		15 h
5. Sound		15 h
6. Nuclear Physics		10 h
		100 h
Optional		
One of:		
1. Astronomy	10 h	10 h
2. Fluids	10 h	
3. Thermal Energy	10 h	
4. Locally Designed Unit	10 h	
		110 h

Physics, OAC (SPH0A)

Units of Study		Time Allocations
Core		
1. Kinematics		19 h
2. Dynamics		19 h
3. Momentum and Energy		16 h
4. Electrostatics		12 h
5. Waves and Light		16 h
6. Early Quantum Theory		8 h
		90 h
*Optional**		
1. Special Relativity	7 or 10 h	20 h
2. Bodies in Equilibrium	7 or 10 h	
3. Electromagnetic Radiation	7 or 10 h	
4. Elementary Particles	7 or 10 h	
5. Locally Designed Unit	7 or 10 h	
		110 h

*Two optional units of 10 hours each or three of about 7 hours each may be selected.

Interrelationships Between the Two Courses

The two Senior advanced-level physics courses – Physics, Grade 12, Advanced Level and Physics, Ontario Academic Course (OAC) – form a continuum. The first course is prerequisite to the second. Teachers of either course should be thoroughly familiar with the subject material in both in order to ensure that overlap between them is minimal and that continuity is provided.

Both the Grade 12 course and the OAC emphasize a balance between substantive *content* and scientific *process*; these are supported by hands-on student activities. The two courses require a balance in *quantitative* and *qualitative* work. The former is accomplished through measurement, graphical analysis, and mathematical problem solving; the latter, through the communication, both verbal and written, of ideas, concepts, findings, questions, and opinions. The use of appropriate language should be stressed. Balance must also be provided through a *science-technology-society* emphasis. Applications and societal implications, identified in each unit of study, should ensure that students perceive physics as a relevant human endeavour, influencing lives, societies, and nations.

Both physics courses should include references to careers in which physics plays a role. This should stimulate an interest in human participation in science and lead to some discussion of the work, responsibility, and influence of physicists. The achievements of Canadian and other physicists should be stressed from time to time.

Teachers of these two physics courses should impress students with the fact that they are surrounded by matter and energy and that they are a part of, and interact with, that matter and energy. In these courses students should also seek to understand and look for meaning in the interactions among scientists, industry, the environment, and all living things. Such meaning should help students to realize that physics can enhance life and be directed towards useful, positive, and peaceful purposes.

The Grade 12 Physics Course

It is important for teachers of this course to be aware of a number of features that are to be included in its design and delivery at the local level.

Foundation treatment. Since some students will take only the Grade 12 course and not the OAC, this is intended to be a survey course, involving seven units of study in physics, six core and one optional. While the course offers an introductory treatment, it must also furnish a foundation for students who wish to take further studies in physics at the OAC level. Thus, it provides for the coverage of a broad range of concepts rather than an in-depth treatment of a few. Most of the material in the Grade 12 course emerges from pre-twentieth-century physics, with the exception of certain topics in core unit 6, which deal with some post-1900 aspects of atomic and nuclear physics.

The Grade 12 advanced-level physics course is designed to provide students with a fundamental background that will enable them to understand physical concepts, apply scientific techniques, handle equipment intelligently and safely, and appreciate the applications and implications of physics in technology and society. This course will be related to the other sciences and will endeavour to raise students' awareness of matter and energy and their interrelationships.

Essay assignments. Since language is an important component of scientific work, students shall be required to write at least two short essays or accounts in the Grade 12 advanced-level physics course. In each unit of study there is one student activity that can be assigned to meet this requirement. Two of these are to be chosen by the students or assigned by the teacher. Joint planning between the physics teacher and the teacher librarian can do a great deal to assist students in obtaining information from the school's library resource centre and other sources. Such planning should occur well in advance of the need for the information. (See also subsections 7.2 and 12.2 in Part 1 of the guideline.)

Mathematical work. Mathematical work is expected in each unit of the Grade 12 course, but the course should not be structured excessively towards mathematical problem solving, at the expense of other important objectives. As a rule, when equations are stated in the courses outlined in this document, simple forms are used. The aim is to avoid undue mathematical complexity. An equation such as $v = u + at$ can be made much more complex by using a form such as $\vec{v}_f = \vec{v}_i + \vec{a}\Delta t$, but the significance of such a form may be appreciated more by students in the physics OAC than in the Grade 12 course. While students must distinguish between *initial* and *final*, *average* and *instantaneous*, and *vectors* and *scalars*, the use of subscripts, Δ as in Δt, and vector notation is left to the discretion of the teacher.

Curriculum emphasis: science-society-technology. Core units 1 and 5 each contain two parts. Part A follows the format used in all of the other units of study. In part B the discussion begins with the *societal implications* and *applications*, proceeds to the *student activities*, and concludes with a consideration of the *objectives* that have been achieved. This variation in approach should challenge students to observe physical phenomena in society, examine applications, and then seek to determine the physical principles involved. This process should provide them with some stimulus towards lifelong learning and should help to achieve, in particular, aims 3, 4, 6, 7, and 11 of the science program (see section 3, "The Aims of the Science Curriculum", in Part 1 of the guideline).

The formats shown in part B of core units 1 and 5 are provided as examples of a science-society-technology emphasis. Teachers are to use this emphasis in these units or in any two or more units selected at their discretion. This emphasis need only apply to a few topics within a unit and shall be clearly identified in the school's course outline. Whether this approach is or is not selected for core units 1 and 5, the objectives, student activities, applications, and societal implications indicated in part B in each of these units are to be treated as mandatory.

The Physics OAC

Optional units. In the Ontario Academic Course the six core units and two or three optional units constitute a complete one-credit course. The optional units can be selected to:

- emphasize mechanics and statics (optional units 2 and 5);
- stress the wave-particle duality concept (optional units 3 and 5);
- accommodate local needs and teacher expertise. In this case two or three optional units would be included to round out the course.

Mathematical work. The OAC in physics is more rigorous than the Grade 12 course and treats many topics in greater depth. It is intended to prepare students for further studies in physics at the university level and therefore places more emphasis on mathematical problem solving than does its prerequisite course. In order to help students realize that various areas of physics can be interrelated mathematically and are often interdependent, opportunities should be provided, particularly towards the end of the course, for students to solve problems involving concepts from two or more areas, such as mechanics, electricity, wave phenomena, and modern physics. In fact, the program may be enriched for some students by the inclusion of a locally developed unit on problem solving at the end of the course. This could be of particular value to those who are proceeding to further studies in physics at a college or university.

Independent study. At least 10 per cent of students' final marks are to be based on their achievement in independent study. Such work should help prepare students to learn on their own without relying constantly on the teacher to direct the learning process. The teacher should encourage students to select a segment of the course or assign students a specific part for independent study. Several short segments or parts from different units in the course might be selected. Independent-study assignments can include such activities as supervised laboratory work, written projects, reports on visits to industry or research facilities, summaries of articles on physics topics, participation in a science-fair project related to physics, the derivation of physics equations through calculus, or a special treatment of problem solving. The range of possibilities is to be determined by the teacher, whose major function is to assist students in identifying topics and appropriate resources and in evaluating their work.

Examinations. The formal examination(s) required of all students and worth from 30 to 40 per cent of the final mark should contain a variety of types of questions, such as alternate-response, multiple-choice, and matching selected-response types; short-answer, completion, restricted- and extended-essay types; numerical types; and, where feasible, types that involve laboratory skills. The formal examination(s) may consist of written and laboratory components. These components may occur close together or weeks or months apart.

Metric Units in Senior Physics

In subsection 8.2 of Part 1 of the guideline, there is a list of metric units with which students are expected to be familiar by the end of Grade 10. In Senior Division courses, the list of metric units with which science students work will naturally expand.

The concept of *coherently* derived units should be understood by students in advanced-level Senior science courses. *Coherency* in a measurement system means that the derived units, such as the cubic metre, joule, pascal, volt, joule per mole, and becquerel, are formed by multiplying and dividing base units without using any numerical factor other than the number one. The joule is a coherent SI unit ($1\ \mathrm{J} = 1\ \mathrm{kg{\cdot}m^2/s^2}$); the calorie is not ($1\ \mathrm{cal} = 4.2\ \mathrm{kg{\cdot}m^2/s^2}$).

Physics teachers are urged to examine the list of primary units (base units plus those coherently derived from base units) in subsection 8.2 of Part 1 and to determine those that are appropriate for physics courses. Prefixed multiples and submultiples of the primary units must be selected as well. Appendix B in Part 1 may provide some help in making the selection.

Unit analysis is a topic that should be included in Senior science. Equations in physics lend themselves very well to illustrating the need to ensure that the units of measure on both sides of an equation are equivalent.

Note that in this document the physical-quantity symbols usually conform to those shown in table 1 of Appendix B in Part 1 of the guideline. Strict adherence has not always been observed, and teachers may use other symbols, since students will find variations in scientific practice.

Physics, Grade 12, Advanced Level (SPH4A)

Core Units

Geometric Optics
Mechanics
Electricity
Electromagnetism
Sound
Nuclear Physics

(100 hours)

Optional Units

Astronomy
Fluids
Thermal Energy
Locally Designed Unit

(10 hours)

Core Unit 1

Geometric Optics

Time: 16 hours

The purpose of this unit is to stimulate students to think about the optics of the human eye and various optical instruments, to help them understand how light can be manipulated, to enable them to solve some mathematical optical problems, and to demonstrate the role that optics can play in their lives, hobbies, and vocations. Note that this unit has two parts (see the subsection entitled "Curriculum Emphasis: Science-Society-Technology" on page 8).

This unit may be divided into topics such as the following:

Part A

- Refraction
- Snell's law
- Lenses and their related images
- Lens formulas
- The human eye and other optical instruments
- Dispersion and the spectrum
- Theories about colour

Part B

- Internal reflection
- Critical angle

Part A

1. Objectives

See the additional objectives in part B of this unit.

Attitudes. Students will be encouraged to develop:

a) an appreciation for the usefulness of optical instruments in enriching their lives (3a, 4a, 4b);
b) an appreciation for the beneficial consequences of corrective eye lenses (4c);
c) an interest in the widespread use of optical instruments in a variety of occupations (3a, 3b, 4b).

Skills. Students will have the opportunity to develop skill in:

a) identifying the refraction and dispersion of light (2a, 2e);
b) measuring angles of incidence and refraction, focal lengths, image and object distances, and image and object heights (2a, 2b);
c) forming real and virtual images with converging lenses (2b);
d) drawing ray diagrams to analyse the effects of lenses (2b, 2d, 5b);
e) determining the index of refraction of a substance (2a);
f) experimentally verifying Snell's law: $n_i \sin i = n_r \sin r$ (2a, 8g);
g) experimentally verifying the equations $1/d_o + 1/d_i = 1/f$ and $m = h_i/h_o = d_i/d_o$ (2b);
h) solving problems based on optical formulas (5b).

Knowledge. Students will be expected to:

a) describe the phenomena of refraction and dispersion and the conditions under which they occur (2a, 2e);
b) distinguish between the effects of converging and diverging lenses (8d);
c) determine image characteristics by means of lens ray diagrams (2b);
d) describe or explain the meaning of the following: refraction, dispersion, angle of incidence, angle of refraction, Snell's law, index of refraction of a substance, converging lens, diverging lens, real image, virtual image, focal length, object distance, image distance, magnification, visible spectrum;
e) gain some understanding of (i) the operation of the human eye and the use of lenses to correct vision problems, (ii) colour blindness, (iii) one or more optical instruments, such as the camera, microscope, telescope, projector, or photocopier (2c, 2d);
f) distinguish between the additive and subtractive theories of colour (2f, 2g);
g) list some careers related to optics (4b, 8e, 8f, 8i).

2. Student Activities

Students are to:

- *a) determine the index of refraction of a medium such as glass, water, or lucite and experimentally verify Snell's law (5b, 8b);
- *b) determine the focal length of a converging lens, verify the equations $1/d_o + 1/d_i = 1/f$ and $m = h_i/h_o = d_i/d_o$, and illustrate the components of these equations in one or two ray diagrams (5b, 8b);
- c) construct a working model of the lens system of an optical instrument such as a camera, projector, microscope, or refracting telescope (5c);
- d) explain, with the aid of a ray diagram, the operation of an optical instrument (5c);
- e) observe the dispersion of white light by a prism;
- f) observe the additive effects of lights of various colours;
- g) examine the subtractive effects of coloured filters on a variety of incident colours;
- h) write a short essay on, or an account of, the use of an optical instrument or the influence of optical devices on society. They may include devices that relate to those mentioned in parts A and B of this unit.

3. Applications

- a) Optical devices, such as eyeglasses, magnifying glasses, microscopes, telescopes, and cameras, have lenses that are carefully made to have specific properties related to their use.
- b) The index of refraction can be used to identify a transparent substance and to determine the concentration of a solution.

4. Societal Implications

- a) Cameras and photography are used for many purposes, such as recording historical events, capturing happy memories, enhancing the arts, influencing the public, invading privacy, and stealing information.
- b) Certain careers and leisure-time activities make use of optical instruments (e.g., photography, filmmaking, optometry, surveying, television production, camera sales).
- c) Most people take their sight for granted. Proper eye care and the consequences of deterioration of sight are often overlooked. Positive steps should be taken to maintain healthy eyes.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

- a) laboratory work and reports, science notes, and oral communication (8c);
- b) problem solving by means of ray diagrams and mathematical formulas;
- c) demonstrated understanding of one or two optical instruments.

6. Safety Considerations

- a) Students should be warned about possible fire and burn risks if candles are used in optical experiments.
- b) Broken glass should be picked up with adhesive tape or a brush and dustpan. Students' hands should not come into contact with broken glass.
- c) If lasers are used in refraction experiments, only equipment that has been approved by a reputable organization such as the Canadian Standards Association, Ontario Hydro, or the Underwriters' Laboratories of Canada should be used.
- d) Students must never look directly at an intense source of light such as the sun or a laser. Teachers must also guard against the possibility of shiny surfaces reflecting laser beams into students' eyes. Protective goggles should be worn.

7. Possible Extensions

Some students might:

- a) do the remaining student activities mentioned in section 2;
- b) dissect a partially frozen eye (e.g., a fresh cow eye) to examine the optical system;
- c) construct lenses, using ice;
- d) examine the magnification effects of drops of such substances as water and oil and explain these effects using ray diagrams;
- e) determine the relationship between the f number and the depth of field of lenses in 35 mm cameras;
- f) study the properties of the electromagnetic spectrum beyond each end of the visible section (students should shield their eyes from ultraviolet radiation);
- g) find examples of the significant use of the spectrum in chemical analysis, astronomy, and spectroscopy.

---

*See the subsection entitled "Student Activities" on page 5.

8. Some Teaching Suggestions

a) It is important that teachers demand good laboratory techniques, careful measurements, and well-drawn ray diagrams.
b) Certain experiments in this unit can quickly be followed by a laboratory test (e.g., finding the focal length of a different lens or the refractive index of another substance).
c) Students can be asked to make an oral presentation based on news articles or optical devices or gadgets brought to the classroom.
d) The juxtaposition of two equilateral prisms can be used to introduce the topic of converging and diverging lenses.
e) To enrich this unit, guest speakers (e.g., a professional photographer, a member of the Canadian National Institute for the Blind, an optician, a lens maker) can be invited to talk to the class.
f) An open-ended discussion can be conducted with students on the importance of optics in their present lives and possible future careers.
g) In the introduction to Snell's law some review of trigonometry may be necessary.
h) Computer simulations of ray diagrams for thin lenses can dramatically illustrate what happens to the image of an object as the object is moved towards or away from the lens.
i) The Canadian Association of Physicists may serve as a useful resource in connection with careers related to various areas of physics.

Part B

Preamble

When students have completed a course in physics, they should have a natural curiosity about physical phenomena. Having observed an object, device, or phenomenon that is based on physical principles, they should wonder about its operation, use, and function and seek to find out why it works the way it does.

In order to assist students in this approach, it is recommended that they study an object, device, instrument, or natural phenomenon first by considering related societal implications and applications, then by engaging in some student activities, and finally by identifying the learning objectives that have been achieved. The following is an example of the approach as applied to the study of the concepts of internal reflection and critical angle. (A second example of this kind of approach is given in core unit 5.)

Students begin by examining the societal implications of the use of binoculars, periscopes, and optical fibres on the basis of *what they are used for*; then, they consider how these instruments are applied in various situations by seeking to find out *what the devices do*. Next, they undertake activities to find out *how the optical devices work*. Finally, they identify the physical principles involved to indicate *what the related science concepts are*.

The societal implications, applications, student activities, and objectives in this example are mandatory for all students taking this course. The science-society-technology curriculum emphasis is recommended for this unit, as explained on page 8.

1. Societal Implications

Students are to consider why optical instruments such as a pair of binoculars and a prism periscope are used. If these are not available, illustrations from catalogues may be used (not pictures that explain how they work). Students should then consider the societal implications of these devices by answering questions such as the following:

- What are they used for?
- Who uses them?
- How much do they cost?
- In what careers are they used?
- Of what advantage or disadvantage are they to society?

2. Applications

Students are then to identify the function of binoculars and periscopes in more detail. They might answer such questions as the following:

- What does the device do? For example, binoculars form enlarged images of distant objects; periscopes allow one to "see around corners".
- When is the device used? For example, binoculars are used at sports events and in theatres; periscopes are used in submarines.
- What other optical device performs the same function? For example, telescopes, microscopes, and hand lenses magnify images; mirrors and optical fibres allow one to "see around corners".
- Do devices such as cameras, overhead projectors, and 35 mm slide projectors belong in the same categories of optical applications? Why or why not? (Wrong answers can be corrected later as students find out how the devices work.)

3. Student Activities

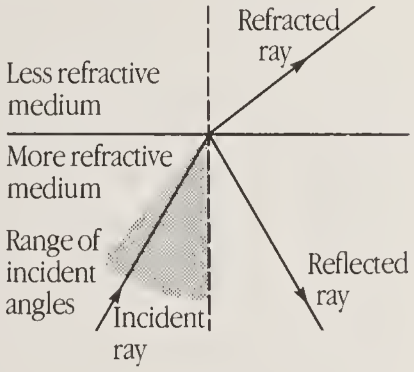
These activities should enable students to explain how binoculars, periscopes, and optical fibres work. Students are to:

*a) find ways in which the total internal reflection of a light beam can occur in a rectangular (45°) prism;
b) observe the optical properties of a fibre-optics tube or fibre bundle;
*c) determine experimentally the critical angle of an internal ray of light in an optical medium such as glass, plastic, or water.

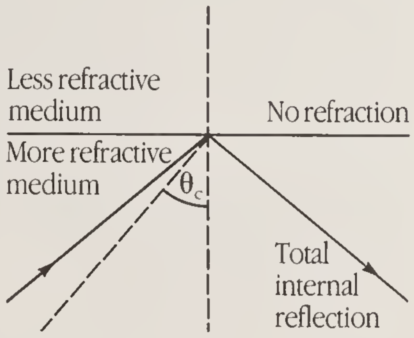
4. Related Scientific Concepts

Students should conclude this part of the unit by making a list of the scientific concepts involved and the information gained. This list might include such items as the following:

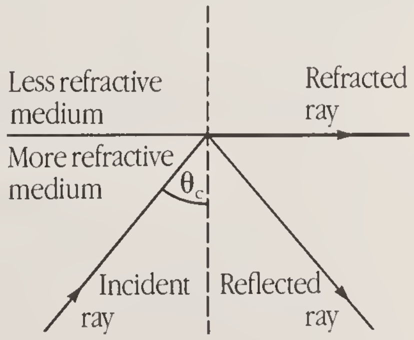
a) For a certain range of incident angles, incident rays of light within the more refractive medium are partially refracted out to the less refractive medium and also partially reflected back within the more refractive medium.



b) Total internal reflection will occur if the angle of incidence is greater than the critical angle, θ_c.

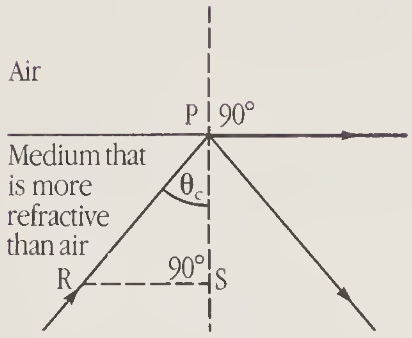


c) The critical angle, θ_c, is the angle of incidence for which the angle of refraction is a right angle.

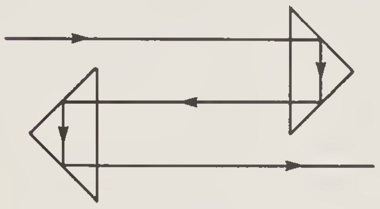


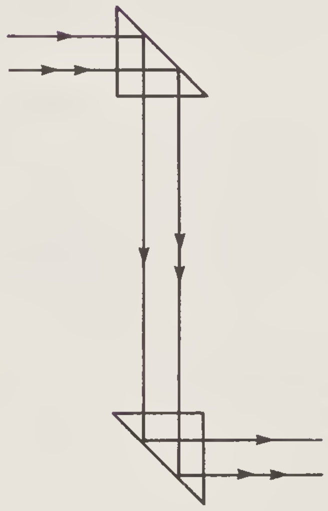
d) Internal reflection can occur in a substance only if the external medium has a lower index of refraction than that of the internal or incident medium.

e) The critical angle, θ_c, for a substance situated in air (strictly in vacuo) is such that $PR/SR = n$ (that is, $\sin \theta_c = 1/n$), where n is the refractive index of the substance. Students should be able to determine θ_c or n, given the other quantity. If the trigonometric ratios are not known, a simple scale diagram will provide a solution.



f) A rectangular glass prism (45°) can be used to reflect light internally (see accompanying diagrams).





Such prisms are used in binoculars and periscopes.

g) The greater the index of refraction (n) of a substance, the smaller its critical angle (θ_c) and the greater the range of incident angles for which total internal reflection will occur.
h) Diamond has a critical angle of only 24°; thus, many facets can be cut in a diamond to provide for multiple internal reflections, which cause a brilliant sparkle.

The following applications and implications can emerge from the above scientific concepts:

- Glass or plastic fibres of very small diameter can be used as internal transmitters of light or communication signals and provide the basis for fibre optics.
- Fibre optics is used in some decorative lamps and illuminated fountains.
- Fibre optics permits the examination of a patient's stomach and other internal tracts, thereby greatly reducing the need for exploratory surgery, with its discomfort, risks, and high costs.
- Fibre optics may render obsolete the use of copper cables for telecommunications, thus reducing the demand for copper, of which Canada is a major world supplier. The increased demand for plastics may then benefit the petrochemical industry.

---

*See the subsection entitled "Student Activities" on page 5.

5. Topics and Objectives

What, then, have been the topics studied in the latter part of the unit? Students might be asked to identify the major topics, which might include the following:

- Total internal reflection
- Critical angle
- The relationship between critical angle and index of refraction, and related problem solving
- Applications: the binocular, the periscope, fibre optics
- Simple ray diagrams

Students might also be asked to identify some of the learning objectives. Such objectives can be clarified by the teacher and stated as follows. Students have been expected to:

- appreciate that fibre optics, binoculars, and periscopes have important uses;
- develop skill in investigating total internal reflection;
- measure the critical angle of a ray of light in a substance;
- discover the principles of fibre optics in a solid tube or bundle of fibres;
- draw and analyse ray diagrams to illustrate internal reflection and indicate how this phenomenon applies to binoculars or a periscope;
- specify conditions for total internal reflection and define *critical angle*;
- state the relationship between the critical angle and the refractive index of an optical medium that is surrounded by air (strictly, situated in a vacuum);
- solve simple problems using their knowledge of critical angle and refractive index.

Note: The terms *optically dense medium, denser medium,* and *less dense medium* can be misleading for two main reasons: (a) Students may think that low mass density and low optical density are related. Such correspondence does not exist; for example, benzene and corn oil, which float on water, have higher refractive indexes than water. (b) The optical density of a medium as defined in, for example, the *Handbook of Chemistry and Physics,* relates to the transparency of the medium and has nothing to do with its refractive index. This document, therefore, uses *more refractive medium* rather than *optically denser medium* and *less refractive* rather than *optically less dense.*

Core Unit 2

Mechanics

Time: 25 hours

Most phenomena in the universe involve motion and energy. The importance of movement and its related energy should be evident to students from such features of their daily lives as physical fitness, sports, and transportation. The intent of this unit is to enable students of science to describe how objects move and to understand what makes them do so. A knowledge of mechanics is essential in understanding electricity, heat, waves, atomic and nuclear physics, and almost all areas of science.

This unit may be divided into topics such as the following:

- Motion in a straight line
- Forces, including gravity
- Newton's laws of motion
- Work, energy, and power

Notes

a) In this unit the study of motion is restricted to motion in a straight line. Circular and projectile motion are included in the physics OAC.

b) The equations shown in this unit do not distinguish between scalars and vectors or between such concepts as average and instantaneous quantities. The identification of such particulars in equations should be included by teachers, provided such details are useful and meaningful to students. See also the subsection entitled "Mathematical work" on page 8.

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of the application of the laws of mechanics to accurate analyses of body motions and related safety measures, to improved achievements by athletes, and to the production of devices that make physical work easier and more efficient (3d-3f, 4a);
b) an interest in the important role that mechanics plays in various careers, such as those of engineers, elevator technicians, architects, auto mechanics, and machinery salespeople (4d, 5e);
c) a curiosity about various kinds of motion that can provide enjoyment, leisure activity, and opportunities for employment (3c, 3e, 4d).

Skills. Students will have the opportunity to develop skill in:

a) accurately measuring displacements and times for uniform and non-uniform one-dimensional motion (2a-2d, 8a);
b) plotting displacement-time and velocity-time graphs (2a, 5c);
c) determining velocity from a displacement-time graph for uniform motion and uniform acceleration at a given time (2a, 5c);
d) determining acceleration from a velocity-time graph for uniform acceleration (2a, 5c);
e) developing complete mathematical solutions to problems that require the use of the following equations:
    i) uniform speed or velocity: $s = vt$
    ii) uniform acceleration: $v = u + at$, $s = \frac{1}{2}(u + v)t$, $s = ut + \frac{1}{2}at^2$
    iii) force: $F = ma$, $F_g = mg$
    iv) work or energy: $W = E = Fd$, $E_k = \frac{1}{2}mv^2$, $E_p = E_g = mgh$
    v) power: $P = E/t$
f) using unit analysis to check answers to solutions (5b);
g) identifying physical quantities in mechanics as vectors or scalars (2a, 5d);
h) using free-body diagrams and vector scale diagrams to help solve one- and two-dimensional force problems (5c).

Knowledge. Students will be expected to:

a) distinguish between (i) uniform and non-uniform linear motion, (ii) distance and displacement, (iii) speed and velocity, (iv) uniform motion and uniform acceleration (2a);
b) identify uniform motion and uniform acceleration in displacement-time and velocity-time graphs (2a);
c) define or explain the meaning of the following: distance, displacement, speed, velocity, acceleration, deceleration, average speed and velocity, instantaneous velocity, uniform motion, uniform acceleration, scalar, vector, force, action and reaction forces, unbalanced force, work, energy, kinetic energy, potential energy, gravitational potential energy, power;
d) know how to determine the unbalanced or applied force on an object in one- and two-dimensional situations, using free-body diagrams and vector scale diagrams (2c);
e) state Newton's three laws of motion and use them to explain situations in which they apply (2c, 3a-3f, 3h, 4a);
f) understand that the force of gravity on an object is proportional to its mass (2c);
g) understand that the acceleration resulting from gravity is fairly constant near the surface of the earth and also know its value (2b);
h) define *newton*, *joule*, and *watt* and express these units in terms of SI base units (2c, 2d);
i) recognize the necessary conditions for work to be done (2d);
j) state the law of conservation of energy;
k) recognize that the work done on an object by an applied horizontal force, in the absence of other forces such as friction, is equal to the gain in the kinetic energy of the object;
l) recognize that the work done on an object to change only its vertical position is equal to the change in its gravitational potential energy;
m) apply the law of conservation of energy to gravitational situations near the surface of the earth;
n) state some historical and personal facts about Isaac Newton, James Joule, or James Watt (5e, 8c);
o) describe an improvement in a sport because of the application of mechanics (3c, 3e, 8e).

2. Student Activities

Students are to:

*a) measure the displacements and times involved in uniform motion and uniform acceleration and plot displacement-time and velocity-time graphs to represent each type of motion (8a);
b) experimentally determine the acceleration resulting from the force of gravity on a freely falling object (6);
c) experimentally confirm Newton's second law of motion;
*d) experimentally determine the amount of work done and the power developed in some mechanical situation;
e) determine the amount of energy needed to maintain some aspect of our current lifestyle (8h);
f) write an essay on the use of energy in modern society or on the application of mechanics to sports.

---

*See the subsection entitled "Student Activities" on page 5.

3. Applications

a) The movements of passengers standing in a bus illustrate the law of inertia, particularly during rapid changes in the vehicle's motion.
b) The principle of inertia helps to explain why a washing machine partially dries clothes during the spin cycle.
c) Sky divers use parachutes to control their speed of descent.
d) Inertia can cause injury, which may be greatly reduced by means of safety devices (e.g., padded athletic equipment, seat belts).
e) The construction of athletic shoes varies according to the type of motion required by different sports. Physical laws and principles have been used to improve sportswear and athletic achievements.
f) Frictional forces are essential in accelerating and decelerating cars, bicycles, and trains.
g) The gravitational and kinetic energy of water can be transformed into electrical energy; this is a major source of Ontario's electrical energy.
h) Jet propulsion is an example of Newton's second and third laws of motion.

4. Societal Implications

a) Implicit in legal restrictions (e.g., laws concerning speed limits, tailgating, traffic lights, seat belts) that regulate traffic and attempt to prevent accidents is a recognition of the principles of mechanics (8d).
b) The kinetic energy of the wind, tides, and flowing water could prove to be a valuable energy source if the methods of transforming it into usable energy do not affect the environment adversely.
c) Our society uses vast amounts of energy to maintain our modern lifestyle. Airplanes often travel half empty, and people frequently use elevators when they could use stairs.
d) A knowledge of the principles of mechanics is important in many careers, such as kinesiology, medicine, engineering, aeronautics, traffic management, navigation, various forms of manufacturing, transportation design and management, and employment related to athletics.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) laboratory experiments and reports, science notes, and oral communication;
b) mathematical problem solving, showing full solutions and including unit analysis;
c) work with graphs;
d) force problems using free-body diagrams and vector scale diagrams;
e) demonstrated understanding of historical factors, career awareness, and societal implications related to mechanics.

6. Safety Considerations

In activity 2b, because of the height involved, students should be warned about standing on stools or desks during the experiment and should be required to use a cushion, large sponge, or pad of paper towels to soften the impact of the object.

7. Possible Extensions

Some students might:

a) determine experimentally the resultant of three co-planar forces acting on one point;
b) study various situations illustrating relative motion (e.g., the motion of a stone relative to the land when the stone is thrown forward from a boat moving upstream in a swift river);
c) determine, with the aid of a long pendulum, the acceleration resulting from gravity;
d) determine the relationship between the energy stored in a spring and the extension of the spring;
e) perform certain activities outside the school, such as measuring the stopping distance of a car or bicycle, the speed of a hockey player, the speed of a baseball or hockey puck, or the acceleration of a skier.

8. Some Teaching Suggestions

a) Teachers are to encourage students to make all measurements to the most precise value allowed by their measuring instruments. The use of a microcomputer as a timing device can be of assistance.
b) Students might be challenged to bring to class gadgets or toys whose operation is based on the principles of mechanics.
c) A part of this unit might be devoted to emphasizing the value of reading about the historical aspects of experiments and the scientists who conducted them, as well as reading the biographies of the scientists after whom various physical units are named.
d) A traffic officer might be invited to discuss the seat-belt law and the implications of the reaction time required to bring a vehicle to a stop.
e) Athletes can be asked to explain applications of the principles of mechanics in their sport.
f) Students can be asked to list and classify examples of motion in their daily life.
g) A microcomputer can be used to assist students in analysing data and graphing experimental results. Programs that will assist students in the drill and review of basic concepts in mechanics might be useful for remedial or independent study.
h) Students can determine the approximate amount of energy needed in a year to operate one flush toilet, to climb a flight of stairs to a bedroom, to provide hot water for showers, to heat a residence, or to maintain electric lighting for the family. This exercise might be done in conjunction with later units of study on electricity and heat.

Core Unit 3

Electricity

Time: 19 hours

Electricity is the main form of energy used in Ontario. It is essential to the maintenance of our society, our standard of living, and our future progress. The purpose of this unit is to help students understand electricity, its properties, its applications, and some environmental issues associated with its production.

This unit may be divided into topics such as the following:

- Current electricity
- Electrical quantities, units, symbols, and related problems
- Electric circuits
- Applications of electricity
- Environmental and societal implications

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a concern over the fact that, although electricity is convenient and "clean", the production and distribution of electricity may harm the environment (4a-4c);
b) a willingness to apply a practical understanding of electricity (e.g., circuitry, measurements, load and cost calculations, reduction of danger factors, beneficial applications) to real-life situations (2d, 2e, 3a, 3c, 4d-4g);
c) a curiosity about some careers and leisure pursuits that require a knowledge of electricity (3c, 3d, 5c).

Skills. Students will have the opportunity to develop skill in:

a) comparing the electrical conducting abilities of different materials (2a);
b) measuring with such electrical instruments as ammeters, voltmeters, and multimeters (2b-2d);
c) safely connecting electrical circuits containing such components as batteries, power supplies, voltmeters, ammeters, conductors, resistors, light bulbs, and switches (2b-2d);
d) deriving Ohm's law from experimental data and related graphs (2c);
e) drawing and interpreting circuit diagrams (2b, 2d);
f) solving, with full solutions, problems involving current, voltage, resistance, energy, power, and cost; such problems should involve formulas, including $Q = It$; $E = QV$; $E = Pt$; $V = IR$; $P = VI$; $R = R_1 + R_2 + R_3 + \ldots$ for the sum of series resistors; $1/R = 1/R_1 + 1/R_2 + 1/R_3 + \ldots$ for the sum of parallel resistors; and cost = price per energy unit × electrical energy expended (2f, 5b, 8a, 8b);
g) operating simple electrical devices and explaining how their circuits function (2e);
h) verifying physical quantities through unit analysis (5b).

Knowledge. Students will be expected to:

a) understand that all matter is made of charged particles and that electrical interactions are responsible for most phenomena studied in physics, chemistry, and biology;
b) describe the characteristics of electrons, protons, neutrons, and ions in order to explain simple electric phenomena (2b);
c) describe sources of electric current and the operation of the voltaic cell;
d) define or state the meaning of electric *charge*, *current*, *potential difference*, *resistance*, *energy*, and *power* and relate each of these electrical physical quantities to their SI units and symbols;
e) define or state the meaning of *coulomb*, *ampere*, and *volt* and know something of the origin of these units and some facts about the scientists after whom they are named (2g, 5c, 8c);
f) understand the principles that explain the potential difference of cells that are connected (i) in series and (ii) in parallel (2b);
g) state Ohm's law and understand what is meant by an ohmic and a non-ohmic resistor (2c);
h) understand the principles that describe or explain the flow of the electric currents in, the potential differences across, and the equivalent resistance of resistors that are connected (i) in series and (ii) in parallel (2d);
i) describe positive and negative environmental effects resulting from society's dependence on electricity (4a-4c, 4f).

2. Student Activities

Students are to:

*a) compare and contrast the electrical conducting abilities of different materials;
*b) measure the total potential difference across several similar cells connected in series and then in parallel, and compare the total potential difference with that across a single cell (5a, 6a, 8d);
*c) experimentally demonstrate Ohm's law for an ohmic resistor and compare the results obtained with a similar set of results for a non-ohmic resistor (5a, 6a, 8d);
d) connect three different resistors, first in series and then in parallel, and with each type of circuit measure the current through and the potential difference across each resistor and derive relationships that describe the electrical properties of series and parallel circuits (5a, 6a, 6d, 8d, 8f);
e) safely operate and then explain the workings of some household, medical, or industrial electrical device (6d, 8e);
f) analyse the consumption and cost of electricity in the home or at school (8b);
g) write a short report or essay on a scientist who has contributed to our understanding of electricity, on the impact of electrical transmission corridors, on electrical safety at home and school, or on the problems that would result from a prolonged electrical blackout (5c).

3. Applications

a) Electricity is used to operate or monitor such lifesaving medical equipment as respirators, lung and dialysis machines, pacemakers, and oxygen tents.
b) A steady source of electrical energy is as essential to the operation of computers as is the silicon chip.
c) Electricity is required for many leisure-time activities, for example, playing an electric guitar, operating a ham radio, making films or videotapes, and sculpting in metal.
d) The following are some of the technical and professional workers who require an understanding of electricity: electricians, electrical engineers, computer designers, robotics engineers, X-ray technicians, artificial-human-limb engineers, appliance designers, appliance repairers, aeronautical engineers, electrical welders, electrical transmission-line installers and repairers, elevator and escalator technicians, auto mechanics, nurses, medical doctors, and scientists (5c).

---

*See the subsection entitled "Student Activities" on page 5.

4. Societal Implications

a) The use of coal, gas, and oil to run some electrical power-generating stations has contributed to the depletion of these natural resources.
b) Sulphur and nitrogen oxides emitted from coal-burning electrical power plants produce acid rain.
c) Many electric-generating stations create thermal pollution in lakes and rivers.
d) Heartbeat, blood pressure, and basal functions are monitored by electrical units in a hospital.
e) Lasers that require electrical energy are used to seal off broken blood vessels in the retina to prevent a form of blindness.
f) The standard of living in North America and elsewhere has been raised substantially because of the use of electric energy.
g) The use of electricity in homes and industries has freed both men and women to enjoy more leisure time and engage in creative pursuits.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) laboratory circuit work, diagrams of the circuits, measurements, tables of data, and practical tests on circuitry;
b) mathematical problem solving involving SI units and full solutions;
c) displayed understanding of historical investigations of electricity, of careers in electricity, or of societal implications of the use of electricity.

6. Safety Considerations

a) All electrical circuitry should be checked by the teacher before the switch is closed where there is the possibility of harm to students or damage to electrical equipment.
b) Each laboratory should have an electrical cut-off switch, and its location should be known by staff and students.
c) An up-to-date safety manual dealing with electrical experimentation should be available in the laboratory and should be familiar to students.
d) Only industrially approved electrical equipment should be used.

7. Possible Extensions

Some students might:

a) study static electricity, including such topics as charging by contact and induction, detection and identification of charges, the Whimshurst machine or Van de Graaff generator, and electrical discharges from surfaces;
b) investigate the factors affecting resistance, using conductors made of different metals and alloys and having different cross-sectional areas, temperatures, and lengths;
c) investigate the electrical distribution system in their school or residence;
d) study the properties of semiconductors and their applications.

8. Some Teaching Suggestions

a) Problem solving should be an important component of this unit. Problems should be practical wherever possible. For example: (i) A student notes that a blender has 900 W stamped on it. She determines roughly how much current it would draw when plugged into a 110 V household socket. (ii) Her friend wants to use a 1500 W toaster-oven while she is using the blender. Is this feasible if the fuse box contains only 15 A fuses? (iii) How much would the blender add to a utility bill annually if it is used for an average of 40 min each week (less two vacation weeks) and the price of electrical energy is 5.4 ¢/(kW·h)?
b) Units of energy in electrical cost problems should involve both the kilowatt hour and the megajoule. It is interesting to note that current rates for electrical energy in parts of Ontario are ranging near 5.4 ¢/(kW·h) or 1.5 ¢/MJ. Some students might prove that these two rates are equivalent.
c) Students should know something about the following scientists, after whom electrical units are named: André-Marie Ampère, Charles Coulomb, Georg Ohm, Alessandro Volta, James Prescott Joule, James Watt.
d) Caution must be exercised to ensure that students correctly use electrical measuring instruments, such as ammeters and voltmeters. An effective method of monitoring their use (particularly the use of ammeters) should be devised.
e) For activity 2e, such items as a food mixer, electric shaver, electric toaster, door chime, electric bell, pacemaker, circuit breaker, electric drill, vacuum cleaner, or electric lawn mower may be used. Students may be asked to bring in old or defective devices for scrutiny in the laboratory. Some may be borrowed from the technology department. The carrying-out of this activity may be postponed until the unit on electromagnetism is taught. All safety precautions are to be observed.
f) Computer software is available to assist students in understanding series, parallel, and combination circuits and solving problems related to them.

Core Unit 4

Electromagnetism

Time: 15 hours

The operation of many electrical gadgets and generators is based on principles of electromagnetism that were discovered in the nineteenth century. Applications of the principles of electromagnetism have revolutionized the twentieth century and have profoundly influenced employment, home life, entertainment, transportation, and industry.

The purpose of this unit is to provide students with opportunities to understand how advances in technology can follow from the discovery of scientific principles and to learn how these principles are applied in the design of common electrical devices.

This unit may be divided into topics such as the following:

- ▸ Magnetism
- ▸ Electromagnets
- ▸ Magnetic fields
- ▸ The motor principle
- ▸ Electromagnetic induction
- ▸ Electric motors, generators, and transformers

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the fact that scientific principles often have technological applications that benefit society (2d, 3, 4a);
b) an appreciation for the different ways in which electrical energy can be converted into other forms of energy and the ways in which other forms can be converted into electrical energy (refer to the voltaic cell from core unit 3, as well as activities 2g and 2h in this unit);
c) an appreciation for scientists and engineers who have been able to design generators that convert energy sources into electrical energy (2i);
d) an awareness of the dependency of society on a reliable, consistent supply of electrical energy;
e) a curiosity about careers that require a knowledge of electromagnetism (4d, 5c);
f) a concern over the fact that advances in electromagnetic technology have disadvantages as well as advantages (4a-4c).

Skills. Students will have the opportunity to develop skill in:

a) using the law of magnetic poles to predict the direction in which a suspended magnet will move because of external magnetic forces (2a);
b) drawing the magnetic field lines around a bar magnet and a horseshoe magnet (2a);
c) making predictions using the appropriate left-hand rule to relate the magnetic field lines to the electron flow in both a straight conductor and a helix (2b, 2c, 8a);
d) drawing diagrams to illustrate the relationship between magnetic field lines and electron flow for both the straight conductor and helix (2b, 2c, 8a);
e) predicting the direction of the force on an electron moving at right angles to the field lines of a uniform magnetic field (2e, 3b);
f) identifying components in various devices that make use of the principles of electromagnetism and drawing a diagram or two to illustrate the function of an electromagnet in at least one appropriate electrical device (2d, 5b).

Knowledge. Students will be expected to:

a) review the law of magnetic poles and state what is meant by the following terms: ferromagnetic substance, magnetic permeability, demagnetization, magnetic field, electromagnet, induced magnetism, domain, magnetic dipole (2a);
b) describe the ferromagnetic domain theory and indicate how it helps to explain certain magnetic phenomena;
c) state the left-hand rules for both a straight conductor and a helix that conduct an electric current (2b, 2c, 8a);
d) describe the main features of an electromagnet and make simple numerical calculations comparing the strengths of different electromagnets (2c);
e) state in simple terms the basic purpose of an electric generator, an electric motor, and a transformer (2f-2h, 5b);
f) state the motor principle and be able to apply the related left-hand rule (2e, 8a);
g) describe, with the aid of diagrams, the operation of a moving-coil galvanometer and a DC motor (2f, 5b);

h) state the law of electromagnetic induction and describe the necessary conditions for the induction of a current in a conductor (2g);
i) list the factors affecting the magnitude of the potential difference induced across a coil and describe the effect of each factor (2g);
j) use Lenz's law to predict the direction of an induced potential or current (2g, 8b, 8e);
k) explain the meaning of alternating current (AC) and why it is used for the large-scale transmission of electricity (2h);
l) label a diagram of an AC generator and explain its operation (2h, 5b);
m) identify the parts of a transformer and explain how it works (3e, 5b);
n) list careers that require a knowledge of electromagnetism (4d, 5c);
o) list common devices that contain an electric motor or a transformer (3e, 3i).

2. Student Activities

Students are to:

*a) perform experiments that (i) illustrate the law of magnetic poles (review only if necessary), (ii) identify some ferromagnetic substances (review only if necessary), (iii) illustrate temporary induced magnetism and residual magnetism, (iv) demonstrate the existence of magnetic field lines, and (v) erase the contents of a cassette tape by means of a magnet (3a);
*b) investigate the magnetic field created by an electric current flowing through a straight conductor (8a);
c) investigate the magnetic field about a current-carrying helix and investigate the factors affecting the strength of such a device (3d, 8a);
*d) investigate the structure of at least one device that contains an electromagnet, such as a lifting electromagnet, a loudspeaker, earphones, a telephone earpiece, an electric bell, a circuit breaker, or a cassette player (3d, 3g, 5b, 8c, 8f);
*e) investigate the effect of electrons flowing through a wire that is placed in a uniform magnetic field (8a);
f) construct a simple DC motor (8c);
g) investigate the conditions under which an electric current is induced in a generator, the direction of the induced current, and the factors affecting the magnitude of the induced potential difference (8d);
h) examine the structure of an AC generator (8d);
i) prepare a short account that describes the operation, some applications, and the societal implications of a device that is based on principles of electromagnetism (5b, 5c).

3. Applications

a) Cassette tapes, videotapes, and computer discs utilize magnetic fields to store information. Because residual magnetism may affect the reading of data, the heads of cassette players and floppy disk drives must be demagnetized periodically.
b) The electron beam in a television tube is deflected by means of electromagnets.
c) The ignition coil in a car works on the principle of electromagnetic induction.
d) Electromagnets are used in electric bells, door chimes, and circuit breakers.
e) A step-down transformer is used in the operation of door chimes, electric-train model sets, calculators, and other devices when they are connected to 110 V sources.
f) The identification strip on banking cards and library books is magnetic.
g) Lifting electromagnets are used for moving scrap ferromagnetic metal.
h) Solenoids are often electromagnets with movable cores.
i) Electric motors rely on electromagnetism and operate many devices such as electric saws, blenders, shavers, lawn mowers, refrigerators, and sewing machines.

4. Societal Implications

a) Electromagnetism has influenced our lifestyles through its use in such commodities as cars and television sets.
b) The thermal generation of electricity from fossil fuels or nuclear fuels is an important energy source. Society has to balance its need for energy against the disadvantages of the waste products created and the possible depletion of non-renewable resources.
c) Long-distance power-transmission lines can be extremely hazardous because of their high voltages; in addition, they require large amounts of land and are unsightly. These factors create issues for debate in regard to energy needs and distribution.
d) Many people are engaged in employment that requires a knowledge of electromagnetism. They include designers, manufacturers, maintenance and repair persons, or salespeople who have jobs related to electric motors, cassette recorders, telephones, loudspeakers, microphones, electromagnetic switching devices, transformers, car ignition systems, and generating and transformer stations.

---

*See the subsection entitled "Student Activities" on page 5.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) laboratory experiments and written assignments;
b) oral and written explanations of the operation of devices based on applications and their societal implications of the principles of electromagnetism;
c) knowledge of careers involving electromagnetism.

6. Safety Considerations

Electric sources having a voltage in excess of 24 V should be avoided in activities in which electromagnetism is investigated. A low-resistance wire connected to a power supply, even of low potential, may heat up to an undesirable temperature.

7. Possible Extensions

Some students might:

a) write a report on the possible consequences of a one-week power blackout, if such a report was not written in conjunction with core unit 3;
b) conduct a survey to compare the number of people using the stairs and the escalators in a shopping plaza, subway station, business office, or apartment building, and calculate the electrical energy that could be saved in one hour if everyone used the stairs for up to three flights up or down;
c) write a short essay on the relationship between science and electrical technology;
d) assemble electric or electronic kits available from commercial suppliers;
e) prepare a photographic essay or slide show illustrating the stages in the generation and transmission of electric energy;
f) investigate the Doppler effect with the aid of electric or electronic equipment.

8. Some Teaching Suggestions

a) In a discussion of electric current, there should be a clear statement about the distinction between electron flow and conventional current. This curriculum guideline recommends the use of left-hand rules based on electron flow. However, it is often the practice in universities, colleges, and industry to use right-hand rules based on conventional current flow. Students should know the left-hand rules but should also be exposed to the fact that another convention exists that is frequently used in technology and postsecondary institutions.
b) Students can be asked to read about some of the historical discoveries and experiments in electromagnetism attributed to scientists such as Faraday, Lenz, and Tesla.
c) Several devices containing electromagnets can be used to make a useful and helpful display. Students can be encouraged to contribute to such a display by donating or making such items as an electric motor or a transformer.
d) Students should have the opportunity to turn the crank on a manual generator and experience the increased effort required when the terminals are shorted out.
e) It should be pointed out that Lenz's law is a direct consequence of the law of conservation of energy. This could be emphasized by asking students to find the flaw in the paradox of perpetual motion or energy.
f) The term *solenoid* should be included in students' vocabularies. Solenoids are used in the starter of a car and in door chimes and as switches in devices such as tape-recorders. Students should realize that solenoids are used to move mechanical parts quickly and accurately. Note that *solenoid* technically refers only to the helix of wire, but colloquially the word refers to both the helix and a movable core inside it.

Core Unit 5

Sound

Time: 15 hours

Sound and music represent significant elements in today's culture. A world without sound would be a very different place. The radio, telephone, and television are examples of technology that make use of sound. Sound and music are used to communicate ideas, information, and emotions. This unit is intended to help students understand some basic concepts of waves and sound.

This unit may be divided into topics such as the following:

Part A

- Vibrations and waves
- Characteristics of sound
- Transmission of sound
- Simple interference of waves
- Resonance: mechanical and acoustic
- Speed of sound

Part B

- The guitar as a source of sound
- Vibrating strings
- Resonance and beats in a musical instrument

Part A

1. Objectives

See the additional objectives in part B of this unit.

Attitudes. Students will be encouraged to develop:

a) an appreciation for the fact that sounds play important roles in their lives (3, 4);
b) a realization that musical instruments employ many principles of physics (3a, 3b, 3d, 3e).

Skills. Students will have the opportunity to develop skill in:

a) measuring the speed of a wave (2b, 5c);
b) classifying waves as either transverse or longitudinal (2a, 2b);
c) solving problems using the equation $v = f\lambda$ (5c);
d) predicting the resultant displacement when two waves interfere, using the principle of superposition (2c, 5c);
e) identifying differences, such as loudness, pitch, and quality, between sounds (6a);
f) observing the phenomena of mechanical and acoustical resonance (2d, 2e);
g) measuring the speed of sound in air (2e, 5c).

Knowledge. Students will be expected to:

a) describe the sources of various sounds;
b) define and use the following terms: vibration, amplitude, period, frequency, transverse wave, longitudinal wave, wavelength, compression, rarefaction, constructive interference, destructive interference, intensity, pitch, quality, overtone, superposition;
c) contrast energy transmission by matter that moves from point A to point B and energy transmission by waves that move from A to B;
d) indicate the difference between transverse and longitudinal waves;
e) state and graphically illustrate the principle of superposition (2c, 5c);
f) state the conditions needed for, and the characteristics of, standing waves;
g) describe what occurs when a wave is reflected (i) at a closed or fixed end and (ii) at an open or free end (2e);
h) name the three main characteristics of musical sounds (8d);
i) state the physical factors that determine the loudness, pitch, and quality of a musical sound (3a, 3b, 6a);
j) describe the effect that a given change in frequency will have on the pitch of a sound (8c);
k) describe the effect that a given change in amplitude will have on the intensity of a sound (4b, 8c);
l) describe what is needed for sound to be transmitted from a source;

m) define *resonance* and give examples of mechanical and acoustical resonance (2d, 2e, 3c, 3d);
n) know the relationships among the speed of sound, its wavelength, and its frequency (2e, 5c);
o) identify the length of an air column that is closed at one end and that will produce resonance at a given frequency (2e, 3e);
p) state the speed of sound in air at 0°C and know how to calculate the speed for other temperatures (5c);
q) compare the speed of sound in various solids, liquids, and gases (3f, 5c).

2. Student Activities

Students are to:

a) determine the period and frequency of a vibrating object, such as a pendulum or a mass bobbing on the end of a vertically suspended spring;
*b) determine the speed of a water wave in a ripple tank or of a wave pulse travelling along a stretched spring, slinky, or rope (5c);
c) graph the wave that is produced when two given waves or pulses interfere with one another (5c);
d) predict and verify the condition required for mechanical resonance to occur with coupled pendulums (3c);
*e) determine the speed of sound by locating consecutive resonance positions in an air column that is closed at one end (5c, 6b);
f) write a brief essay or report on applications or societal implications of sound; these may include ideas related to items mentioned in parts A and B of this unit.

3. Applications

a) Sounds produced by humans, animals, musical instruments, and various devices can be identified by their characteristic tones.
b) The specific tones of particular sounds allow them to be duplicated in speech and by music synthesizers.
c) Resonance can cause glass to shatter and has caused suspension bridges to collapse.
d) Resonance is utilized to improve the intensity and quality of the sounds of musical instruments (e.g., in the sound box of a violin).
e) Air columns, closed at one end or open at both ends, are found in pipe organs and wind and brass instruments.
f) The depths of the sea and the location of reefs, sunken ships, submarines, or schools of fish can be determined by means of the transmission and reflection of sound.

4. Societal Implications

a) Electronic music has been created as a result of knowledge about the physics of sound.
b) Noise or sound pollution has become a problem in many occupations and residential areas.
c) Music and various forms of sounds have provided for a great number of careers, including those of musicians, designers and producers of musical instruments, sales personnel in music stores, writers of musical pieces, producers of musical performances, personnel who assist in controlling the sound in musical productions, acoustical engineers and technologists, architects, and those engaged in work involving sonar and ultrasound.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) investigations, observations, and experimental work;
b) laboratory reports;
c) solutions to problems involving interference, the speed of sound, and acoustical resonance.

6. Safety Considerations

a) Students should not be exposed to high-intensity sounds.
b) If glass resonance tubes are used, students should be warned to prevent the vibrating tines of a tuning fork from touching the glass, as the glass could be shattered.

7. Possible Extensions

Some students might:

a) determine the speed of sound by timing echoes from a distant reflecting surface;
b) investigate resonance positions in air columns that are open at both ends;
c) investigate the operation of different musical instruments;
d) compare music and noise;
e) study the structure, function, diseases, and care of the ear;
f) investigate the sources and effects of noise pollution and identify the methods used to reduce such effects;
g) investigate the literature on the effects of loud noises on hearing and the law regarding sound levels in the workplace and at school;
h) investigate the inverse square law of sound intensity.

---

*See the subsection entitled "Student Activities" on page 5.

8. Some Teaching Suggestions

a) Audio and audio-visual aids can be used to reinforce many concepts in this unit.
b) If sufficient quantities of similar kinds of equipment are not available, student investigations can be done by rotating students from one piece of equipment to another.
c) An oscilloscope can be used to illustrate visually that a change in frequency will alter the pitch of a sound, that a change in amplitude will alter its loudness, and that a change in the shape of a wave will alter the quality of a sound.
d) A music synthesizer can be used to demonstrate properties of musical sounds.
e) Computer programs can be used to simulate the superposition of waves.

Part B

In this part of the unit, students will study the guitar first from the point of view of its widespread use and popularity, especially among young people, and then as an application of stringed instruments as producers of sound. This will lead to experimentation and end with a consideration of the scientific principles and concepts involved. Other stringed instruments can be used, depending on students' interests and the availability of equipment. (See also the preamble to part B in core unit 1.)

1. Societal Implications

Students should be asked to bring guitars to class or to borrow some from the music department. The class discussion should centre around such questions as the following:

- Who uses guitars, and for what different kinds of purposes are they used?
- How much do they cost? What is their price range?
- What impact have they had on music and society?
- What kinds of careers involve a knowledge of the guitar or the ability to play one?

2. Applications

Students should identify the function of the guitar in more detail by investigating such questions as the following:

- What are the different types of guitars?
- What other stringed instruments perform a similar function? (Examples include the ukelele, banjo, and mandolin.)
- Do all stringed instruments (e.g., violin, bass, harp, piano) operate in the same way? What are the fundamental differences among them?
- How is a guitar tuned?

3. Student Activities

Students are to:

*a) determine the effect that at least two of the following have on the frequency of a vibrating string: length, tension, diameter, density;
b) observe the effect of changing the mass distribution of the tines of identical tuning forks on the frequency of the beats that are produced;
c) determine how a guitar may be tuned using the phenomenon of beats and demonstrate the effect of the sound box of the guitar on the tone and intensity of the notes.

4. Related Scientific Concepts

Students should be able to identify the scientific concepts and information that they have acquired from this part of the unit, including items such as the following:

a) The length, tension, diameter, and density of a vibrating string have an effect on its frequency. (More specific statements should be included; for example, decreasing the length of a string increases its frequency.)
b) Resonance is often responsible for the quality and intensity of sounds produced by musical instruments.
c) Beats can assist a musician in tuning a guitar.

5. Topics and Objectives

Students should be asked to identify the major topics studied in this part of the unit, which might include the following:

- The guitar as a source of sound
- Factors affecting the frequency of a vibrating string
- Resonance in a stringed instrument
- Beats: tuning an instrument

Students should increase their understanding of the learning process if they can state some of the objectives in studying this part of the unit. It is recommended that they attempt to list such objectives, which may be stated as follows: Students have been expected to:

- describe the effects that length, tension, diameter, and density have on the frequency of a vibrating string;
- explain how a musician playing a stringed instrument produces sounds of different frequencies;
- explain how the phenomenon of beats can be used to tune a musical instrument;
- describe several effects that musicians have had on society.

---

*See the subsection entitled "Student Activities" on page 5.

Core Unit 6

Nuclear Physics

Time: 10 hours

Students frequently encounter such terms as the following: ionization smoke detector, radiation therapy, nuclear reactor, radioactive material. The purpose of this unit is to make students aware of the scientific and societal implications of such terms and the extent to which nuclear physics can affect their lives. This unit should also equip them with some basic knowledge required by citizens who will be making decisions about the future role of nuclear technology.

This unit may be divided into topics such as the following:

- Atomic and nuclear structures
- Radioactivity
- Radioactive decay
- Nuclear fusion and fission
- Applications of nuclear physics

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a sense of social concern over the reality that technological applications of nuclear physics involve risks, which must be weighed against the benefits of nuclear technology to society (3c-3e, 4a, 4b, 4d);
b) an appreciation for the fact that scientific knowledge has a significant role to play in political decision making (4a-4c, 8c, 8d);
c) a responsible concern for the need for realistic safety precautions in the handling and storage of radioactive materials (3d, 3e, 6a-6d);
d) a curiosity about the new knowledge uncovered by ongoing research in nuclear physics (5c, 8d).

Skills. Students will have the opportunity to develop skill in:

a) observing cloud-chamber tracks and the absorption of radiation (2a, 2c);
b) observing and describing the effect that different absorbers have on different types of radiation (2c);
c) measuring with a Geiger counter (2b, 2c);
d) relating film exposure and Geiger counter readings to the penetrating power and ionizing ability of radiation (2c);
e) graphing data for radioactive decay and interpolating values for half-life (2b, 8e);
f) using a theory to explain observations, for example, the cloud-chamber tracks (2a);
g) obtaining information about current scientific developments related to nuclear science from books, newspapers, journals, and other sources (5c, 8c);
h) inferring the properties of radiation from experimental data, for example, the deflection of rays by a magnetic field and the observed lengths of cloud-chamber tracks (2a, 2c);
i) interpreting some common nuclear-decay chains;
j) determining the energy equivalent of a given mass or the mass equivalent of a given amount of energy (5d);
k) doing simple calculations involving half-life (5d);
l) calculating the energy released through the decrease in mass in a fusion reaction (5d).

Knowledge. Students will be expected to:

a) list the primary forces of nature;
b) describe the Bohr model of the atom, draw a diagram of the atom based on the Bohr model, and describe some characteristics of each part;
c) describe the Rutherford model of the atomic nucleus;
d) use the notation $^{A}_{Z}x$ to describe and identify common nuclear isotopes;
e) define the following terms: atomic number, atomic mass number, isotope, radioisotope, radioactive decay, background radiation, half-life, mass defect, energy mass equivalent, nuclear fusion, nuclear fission, chain reaction, annihilation, alpha particles, beta particles, gamma rays, X rays;
f) describe several ways of detecting radioactive emissions, for example, through the use of a cloud chamber, photographic film, a Geiger counter, and a dosimeter (2a-2c);
g) use the ionization theory to explain how radiation is absorbed by matter (2a-2c);
h) compare alpha particles, beta particles, and gamma rays as to mass, charge, speed, penetrating power, and ionizing ability (2c);
i) write nuclear equations for alpha and beta decay (2b);
j) describe the basic operation of the CANDU reactor and explain the function of the fuel rods, coolant, moderator, and control rods (8d);

k) define the becquerel (Bq) as a measure of radioactivity and the gray (Gy) as a measure of absorbed radiation dosage, that is, energy absorbed per unit mass (8f);
l) discuss the sievert (Sv), the unit of dose equivalent by which radiation doses are measured, and illustrate the use of the sievert in expressing typical amounts of dose equivalents received by human bodies (8f);
m) compare different kinds of radiation in terms of the biological damage they can cause;
n) describe some consequences of overexposure to radiation;
o) describe the problems involved in disposing of waste products from a nuclear reactor (4b);
p) describe a practical application of a radioisotope (3d, 4d).

2. Student Activities

Students are to:

*a) observe radiation tracks in a cloud chamber or in photographs of cloud-chamber tracks (6a-6d);
*b) determine the half-life of a radioisotope using a Geiger counter and a short-lived daughter extracted from a minigenerator (6a-6d, 8b);
*c) observe and compare the penetrating power of alpha and beta particles (6a-6d);
d) observe and describe the operation of an ionization smoke detector (3a);
e) write a short essay on a nuclear issue (e.g., the medical uses of nuclear physics, the nuclear industry in Canada, the pros and cons of nuclear weapons) or on careers related to nuclear physics (4d, 4e, 5b, 5c, 8c, 8d).

3. Applications

a) An ionization smoke detector utilizes the ionizing property of alpha particles.
b) The relative concentration of carbon 14 is used to estimate the age of archeological specimens through the principle of half-life.
c) Irradiation by gamma rays can extend the storage life of crops and the shelf life of food.
d) Radioisotopes are used as tracers in medicine, agriculture, and industry.
e) Cobalt 60 is used in the treatment of cancer.

4. Societal Implications

a) The harnessing of thermonuclear fusion may someday provide a cleaner source of nuclear energy.
b) Fission reactors are a widely used source of energy. The long-term storage of the hazardous by-products from fission reactors remains a problem that must be solved.
c) The proliferation of nuclear weapons poses a grave threat to human survival.
d) Society benefits from the application of radioisotopes in medicine, agriculture, and industry.
e) Professionals, technologists, and technicians in medicine, radiology, agriculture, mining, engineering, and science are often engaged in work related to nuclear physics. Their work might involve such activities as nuclear research, radioactive tracing and diagnosis, radiation therapy, detection of metallic flaws, maintenance of quality control, measurement of material thicknesses, determination of wear and tear on automobile tires and parts, improvement of detergents, and control of pests.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) laboratory experiments and reports;
b) projects (e.g., a report based on a reading assignment, an experimental investigation, or a class debate);
c) knowledge of the historical development and societal implications of nuclear physics, or knowledge of careers requiring a background in nuclear physics;
d) problem solving.

6. Safety Considerations

a) Government regulations regarding the possession of radioactive materials are to be carefully observed.
b) Radioactive materials shall be stored in a secure location, and an inventory must be maintained.
c) Students are to be warned of the dangers of ingesting radioactive materials and are to be required to wash their hands after handling the materials.
d) Student projects involving radioactive materials must be supervised closely.

---

*See the subsection entitled "Student Activities" on page 5.

7. Possible Extensions

Some students might:

a) measure the radioactivity of dust collected in the filter of a vacuum cleaner, monitor the levels for several days, and make a correlation with the pollution index;
b) investigate the relationship between radiation intensity from gamma rays and the thickness of an absorber, stating how this relationship influences the shielding required for nuclear reactors and other strong sources of radiation;
c) design and perform an experiment to show that beta rays can be deflected by a magnetic field;
d) design and perform an experiment in which they use a radioactive tracer to investigate some aspect of plant growth;
e) participate in a debate about nuclear energy and nuclear weaponry.

8. Some Teaching Suggestions

a) Students should read about historical experiments in nuclear physics (e.g., those performed by Becquerel, the Curies, and Rutherford), especially experiments that cannot be duplicated in the classroom.
b) Activity 2c may be performed with the aid of a Geiger counter and thin sheets of different materials.
c) A supply of literature and audio-visual materials relating to the issues of nuclear energy and the nuclear arms race should be maintained. Students should be encouraged to send for information on both sides of the nuclear debate or for information about current developments in nuclear technology.
d) A class trip to a nuclear-power generating station might be arranged. The issue of nuclear energy in society may be handled by role playing, class debate, or inviting speakers to the school.
e) Computer software can be used to simulate radioactive decay, to show the operation of a reactor, and to teach fundamental concepts of nuclear physics.
f) Some reference should be made to the following SI units of measure in this unit of study. However, they should not be overemphasized.

- The becquerel (Bq) is used to measure activity in radionuclides. It is the special name for *second to the negative one* when used as the SI unit of activity ($1\ \mathrm{Bq} = 1\ \mathrm{s}^{-1}$). The quantity symbol for *activity* is A.
- The gray (Gy) is used to measure, for any ionizing radiation, the mean energy imparted to an element of irradiated matter divided by the mass of the element. It is the special name for *joule per kilogram* when used as the SI unit of absorbed dose ($1\ \mathrm{Gy} = 1\ \mathrm{J/kg}$). The quantity symbol for *absorbed dose* is D.
- The sievert (Sv) is used to measure a dose equivalent. It need not be defined in this course, since it depends on the quality factor and any other modifying factor of the tissue that receives the radiation. The word *sievert* is the special name for *joule per kilogram* when used as the SI unit for dose equivalent ($1\ \mathrm{Sv} = 1\ \mathrm{J/kg}$). The quantity symbol for *dose equivalent* is H.

Other units that were formerly used to measure radiation characteristics may still appear in some references. Therefore, teachers should be aware of the following relationships:

- 1 Ci (curie) = 37 GBq
- 1 rad = 10 mGy
- 1 rem = 10 mSv

Optional Unit 1

Astronomy

Time: 10 hours

> Astronomy is useful because it raises us above ourselves. It is useful because it is grand. It shows us how small is one's body, how great one's mind. One's intelligence can embrace the whole of this dazzling immensity, in which one's body is only an obscure point, and enjoy its silent harmony. Thus we attain self-insight, something which cannot cost too dear, since this insight makes us great.
>
> *Modified from a statement by* Henri Poincaré

In its attempts to deal with the origin and behaviour of matter and energy within the universe, astronomy embraces the broad generalizations of all physical science. By its very nature, dealing as it does with distances, time frames, and mass-energy scales that dwarf terrestrial experiences, the astronomical laboratory imposes on the astronomer an observational and theoretical mode, as opposed to the experimental and replicable mode in which matter and energy are directly manipulated in the laboratory. The astronomer's contact with these "natural experiments" that occur in the universe is through the electromagnetic radiations that they produce. Consequently, the thrust of modern astronomy concerns the construction and placement of suitable detectors to receive the radiations emitted by celestial objects – gamma rays, X rays, ultraviolet rays, visible light, and infrared and radio waves. The interpretation of the information received is based on the belief that the physical laws governing matter and energy are universal and applicable to remote regions of space and time. The purpose of this unit is to introduce the student to the sun and stars and to illustrate how our knowledge of physics permits us to understand their nature, development, and behaviour. Some of the ideas developed in the units on geometric optics and nuclear physics will find application in this unit.

This unit will require certain background information and skills. Students should be familiar with the following:

- basic principles of geometric optics, laws of reflection and refraction, the meaning and interpretation of ray diagrams, and some use of optical instruments
- the common subatomic particles and their properties, nuclear change, and the balancing of nuclear equations
- the basic energy-level structure of the atom and the Bohr-Rutherford model
- the concept of temperature and the kinetic-molecular theory

This unit may be divided into topics such as the following:

- The continuous spectrum
- Emission and absorption line spectra
- Telescopes and accessories: extending our senses
- Distances to the stars: parallax
- Distances to the stars: the inverse-square law
- Physical properties of the stars: the luminosity-temperature diagram
- Physical structure of a star: nuclear fusion
- Nucleosynthesis and supernovas

The treatment of the properties and structure of the sun should be woven throughout the above sequence.

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an awareness that astronomy is an observational rather than an experimental science (2a-2c);
b) an awareness and appreciation of the nature of the universe and the beauty, variety, and nature of the structures in the universe (2a, 4c, 4d);
c) an awareness that scientific principles and theories, with their strengths and limitations, may be used to understand the cosmos (3c);
d) an awareness of the vastness of the universe and of our place in it (3c, 4c, 4d);
e) an appreciation for the role of conceptual model building in science (3c, 4c);
f) a concern for the growing light pollution that is steadily eroding our view of the night sky (2a, 4d).

Skills. Students will have the opportunity to develop skill in:

a) constructing and interpreting a graph for the purpose of classifying objects such as stars (2f);
b) balancing nuclear equations (3b, 3e);
c) observing the photosphere of the sun safely (2b, 3d);
d) estimating the distance of objects by triangulation, with the aid of parallax, and by applying the inverse-square law for light (2i, 2j, 3f);

e) understanding conceptual models (3c, 4c);
f) projecting the spectrum of the sun (2c, 2d, 3a);
g) identifying certain elements by observing their spectra (2d, 2e, 3a, 6b);
h) locating and observing, with the aid of a star chart and the unaided eye (or with binoculars or a telescope if available), certain celestial objects representative of the stages of stellar development (2a, 2g, 3c, 4c);
i) conceiving of astronomical distances, masses, densities, volumes, and powers (2f, 2i, 2j, 3c, 4c, 8a).

Knowledge. Students will be expected to:

a) state or describe the following physical dimensions and characteristics of the sun: its mass, diameter, power, colour, "surface" temperature, chemical composition, and mean distance from the earth; and have some idea as to how at least three of these features are determined (2b, 2c, 2f, 3d, 8a);
b) describe the continuous spectrum of visible light and extend the description to include the infrared and ultraviolet regions (2d);
c) understand that most of our knowledge about objects in the universe is obtained from an analysis of their radiation (2b-2e, 3a);
d) describe the formation of emission and absorption line spectra and explain how they can be used to determine the chemical composition of a gas (2d, 2e, 3a);
e) explain how Wien's law provides information about the "surface" temperature of a star (2f, 2h);
f) explain why telescopes, spectrographs, and photometers must be used in astronomy to extend our senses (2g);
g) describe a telescope's performance in terms of light-gathering power, resolution, and magnification (2g);
h) illustrate, with the aid of ray diagrams, the formation of an image by a reflecting or refracting telescope (2g);
i) explain the phenomenon of parallax and, with the aid of a diagram, derive and understand the relationship between parallax and distance (2i, 3f);
j) state and apply the inverse-square law for light (2j);
k) sketch a luminosity-temperature diagram for the sun and stars and interpret the main sequence, red supergiant, blue supergiant, red dwarf, and white dwarf regions in terms of the following properties: luminosity, temperature, diameter, mass, density (2f, 8a);
l) recognize that the luminosity-temperature diagram shows the properties of stars in various stages of their development (2f, 2h, 2j);
m) explain the significance of changes in either the temperature co-ordinate or luminosity co-ordinate on the luminosity-temperature diagram (2f, 2h);
n) outline the details of the proton-proton chain of nuclear changes that are postulated to occur within the sun (3b-3e);
o) balance the net nuclear fusion equation for the proton-proton chain and use $E = mc^2$ to calculate the energy involved (3b, 3d);
p) have some idea, without necessarily giving a detailed explanation, as to how astronomers estimate the age of the sun;
q) describe the balance between pressure and gravity that exists within a star (8c);
r) describe the possible life history of a star of one solar mass from birth to death and indicate those changes, both internal (e.g., temperature, density) and external (e.g., diameter, "surface" temperature, luminous power), that might accompany its evolution (3c);
s) describe a supernova explosion and explain the changes within the core of a star that are believed to be responsible for such an outburst (3e);
t) explain the connection among a supernova explosion, nucleosynthesis, and the formation of new stars (3e).

2. Student Activities

Students are to:

*a) observe the night sky, noting in particular the colours of the stars (5a, 8f);
b) construct a pinhole projector and, with the aid of the projector, observe an image of the sun's photosphere (5a, 6a);
c) project and observe the sun's spectrum (5a, 6a);
d) observe both the continuous visible spectrum and the line spectra produced when certain elements are heated to incandescence or excited by some other method (5b, 6b);
*e) determine the chemical identity of a mixture of elements by comparing photographs or drawings of the spectrum of the mixture with photographs or drawings of the spectra of known elements (3a, 5b, 8b);
*f) plot a luminosity-temperature diagram for the brightest and the nearest stars (5c);
g) demonstrate the light-gathering ability of a lens by using it to gather sunlight and compare (theoretically) its light-gathering ability with that of the human eye (5d, 6a);
h) observe the colour changes of an incandescent light bulb as the current and, hence, the temperature are changed (6b);
i) demonstrate the phenomenon of parallax (3f, 5d);
*j) demonstrate the inverse-square law for light by using light bulbs that have different wattages and that are located at different distances from a detector (5d, 6b).

---

*See the subsection entitled "Student Activities" on page 5.

3. Applications

a) Spectroscopy is an important method of chemical analysis.
b) Thermonuclear fusion is a potentially important energy source for the human race.
c) A study of the stars provides a comprehensive understanding of physical processes and mechanisms both on earth and throughout the universe.
d) The sun is the primary source of energy for the earth.
e) Almost all of the elements in the periodic table can result from nucleosynthesis within the interiors of stars.
f) The depth determination provided by our binocular vision and the distance measurements made by range finders (e.g., on some cameras) are both based on the phenomenon of parallax.

4. Societal Implications

a) Astronomy is a scientific endeavour involving the worldwide co-operation and collaboration of scientists and technologists.
b) The development of a program of space exploration has created new products, industries, and occupations. The spin-off from the technology developed for this space research has enriched the lives of many people.
c) The astronomer's description and modelling of distant and foreign vistas capture the imagination of the public and contribute to a sense of shared exploration and intellectual excitement.
d) Astronomy provides an enjoyable leisure-time activity for many people and a lifetime vocation for others.

5. Evaluation of Student Achievement

At least 30 per cent of the term mark for this unit is to be based on students':

a) recorded observations of the night sky and characteristics of the sun;
b) analyses of chemical spectra;
c) luminosity-temperature diagrams of stellar properties;
d) investigations of optical phenomena.

6. Safety Considerations

a) Students must be instructed never to look directly at the sun because of the potential damage to their eyes. This is especially important when they are using optical aids such as telescopes, binoculars, lenses, and mirrors. The sun can be observed by projecting its image onto a screen.
b) Students should be instructed to observe normal safety precautions when they use Bunsen burners, chemicals, or electrical apparatus.

7. Possible Extensions

The following activities are optional and are to be used as suggestions for interested students. The list is unusually long because of the broad scope of astronomy and because of the diverse interests that students have. Some students might:

a) estimate the order of magnitude of the power of the sun by performing a simple calorimetric experiment in which the radiant energy of the sun is captured by water in a blackened vessel. By knowing the collecting area of the vessel, the time the vessel is exposed to the sun, and the distance to the sun, students should be able to estimate the sun's power. Using the relationship $E = mc^2$, students can then estimate the equivalent rate of conversion of mass into energy. By hypothesizing the proton-proton chain model for the fusion reactions that occur in the core of the sun, they can estimate the rate of conversion of hydrogen into helium. This estimate, combined with a measure of the mass of the sun and the proportion that is hydrogen, might give an approximation for the lifetime of the sun. Students should discuss the validity of this method;
b) use a suitably mounted telescope or binoculars to project an image of the sun in order to map the location and behaviour of sunspots. An analysis of the changing location of sunspots will provide information on the sun's rotation;
c) investigate such aspects of solar-terrestrial relations as the following: the Solar Constant (measurement and variations), the solar wind, geomagnetic disturbances, auroras, ice ages, sunspot cycles and tree-ring growth, the proposed Solar-Polar Mission;
d) measure the sun's diameter using a pinhole projector. Calculations can be based on the diameter of the sun's image, the distance from this image to the pinhole, the distance of the sun from the earth, and the geometry of similar triangles;
e) determine the masses of the components of a binary star system. Such systems provide the only direct method of measuring the masses of stars;

f) use star charts to become familiar with the seasonal and circumpolar stars and constellations;

g) investigate the use of Cepheid pulsating variable stars for measuring the distance to stars and establishing a scale of distance in the universe. These Cepheid variables of known power can be used, along with the inverse-square law for light, to determine the distance of a star from its apparent brightness;

h) construct a simple reflecting or refracting telescope from a kit or from available parts;

i) carry out a project involving a library search and subsequent oral or written report on (i) the historical development of a particular concept in astronomy, for example, the use of Cepheid pulsating variables as distance indicators; (ii) the life, times, and contribution to astronomy of a famous astronomer, for example, Nobel laureate S. Chandrasekhar; (iii) a current topic of active research or debate in astronomy, for example, the solar neutrino problem; or (iv) the techniques and equipment used in analysing invisible electromagnetic radiation, for example, radio radiation. This unit (and astronomy in general) lends itself to resource-based learning, provided the resource material is up to date;

j) visit an astronomical observatory, talk with professional astronomers, and observe the tools and equipment that they use;

k) organize or take part in a "star night" on the theme of stellar evolution from a star's "birth" to "death". Good representative examples of the following stages are visible at most times of the year: birth (nebulas), main sequence, red giant, planetary nebula, and white dwarf. A knowledgeable resource person with good telescopic equipment is essential for an activity of this kind. A local amateur astronomer might welcome the opportunity to show off these celestial objects to students;

l) make systematic measurements of the brightness of variable stars. Much of our knowledge of stellar properties and development has been obtained from the study of variable stars, and this is one area in which an amateur astronomer with modest equipment can contribute to astronomical research. A "Beginner's Observing Kit" can be obtained from the American Association of Variable Star Observers;

m) take colour photographs of stars, constellations, polar and equatorial star trails (from darker sites), auroras, sunrises, and sunsets. A 35 mm single-lens reflex (SLR) camera with fast film (ASA 400 or higher) mounted securely on a tripod will produce constellation slides with negligible trailing if the shutter is held open for about thirty seconds;

n) investigate the results of theoretical modelling of the interior of the sun and stars. The ability of astronomers to see directly into the interior of the sun is limited to a few hundred kilometres by the opacity of the sun's outer layers. However, theoretical models of the interior have been developed, based on our understanding of the gas laws, atomic and nuclear physics, and gravity. Electronic computers have been used extensively to calculate such models and to predict the physical properties (e.g., pressure, density, temperature, energy production and flow) at various distances from the sun's centre. Students might plot such data on suitable graphs and investigate the assumptions on which such modelling is based;

o) produce and observe an absorption-line spectrum in the laboratory. This interesting and challenging experiment involves first producing a continuous spectrum from an incandescent bulb and then introducing a vapourized element, such as sodium, between the bulb and the spectroscope. This can be done by heating a sample of a sodium salt in a flame.

8. Some Teaching Suggestions

a) In astronomy the distances are so vast, the masses so great, and the temperatures, pressures, and densities so extreme that it is instructive to employ comparisons with more familiar situations. For example, teachers might discuss the characteristics of the sun in terms of those of the earth, or the distances to the nearest stars in terms of the distance from the earth to the sun or in terms of the time that would be required by the fastest jet aircraft to travel such distances.

b) Audio-visual materials, such as slide sets, films, videos, and magazines, are important aids in illustrating astronomical topics. It is important that such material be as up to date and authoritative as possible. The Royal Astronomical Society of Canada, the National Museum of Science and Technology, the McLaughlin Planetarium, the Ontario Science Centre, Science North, NASA, and the U.S. National Air and Space Museum are possible sources. Many excellent astronomy programs are aired on public television. Nevertheless, care should be exercised to ensure that this unit does not become a film festival. Teachers should incorporate short, illustrative segments of films into their lessons. Naturally, copyright regulations must be observed.

c) When introducing the concept of the delicate balance between gravity and gas pressure in a star, the teacher can present a helpful analogy by inflating a balloon and drawing students' attention to the balance between the elasticity of the balloon material (which tends to collapse the balloon) and the internal gas pressure (which tends to expand it). Changes in the gas pressure are reflected in changes in the radius and volume of the balloon, just as changes in the internal structure of a star, as it evolves, are reflected in changes in the radius of the star.

d) Core unit 1, "Geometric Optics", should be studied before any lessons on telescopes are taught. Core unit 6, "Nuclear Physics", should be studied before the energy source of the stars is discussed. Students should be familiar with subatomic particles, the mass-energy equivalence, and the balancing of nuclear equations.
e) Direct observation of the sky is important in making this unit meaningful, but allowance must be made for the weather. To ensure that unfavourable weather does not delay the unit, activity 2a (and perhaps 2b and 2c), for instance, should probably be conducted whenever weather conditions are good, before the main period of time scheduled for the rest of the unit.
f) There has been a great increase in the availability of astronomy-related computer software, ranging from sky-generation programs that enable the user to observe the appearance of the sky at different locations and times, through elegant geometric optics ray-tracing programs, to simulations of space flights to distant stars. Students usually enjoy working with these programs, and teachers should consider using this new technology.
g) A guest speaker can be invited to address the class or a class visit to a local planetarium can be scheduled. The guest lecture or planetarium show might be used to enrich the topic of stellar structure and evolution.
h) In the study of astronomy, particularly in discussions on the origin or history of the universe, the terms *evolution* and *creation* often lead to misunderstanding and controversy. In this unit *evolution* refers to the development and aging of stars and galaxies. In this context the *theory of evolution* then refers to the most widely accepted scientific explanation of these stellar and galactic processes. The term *creation* is not used, since it usually implies a creator and related religious perspectives rather than scientific observation. However, students need to understand that science continually raises philosophical questions that go beyond its competence or purview. Such questions may be discussed in science courses if time permits. When handling sensitive issues, teachers are to adopt the principles outlined in subsection 10.2 in Part 1 of the guideline.

Optional Unit 2

Fluids

Time: 10 hours

Fluids, including air and water, are a vital part of our lives. The characteristics of fluids enable us to move below and across the surface of water bodies and above the surface of the earth. Fluids are essential in most industrial processes and form the basis of all hydraulic and pneumatic devices. The purpose of this unit is to enable students to study the properties of fluids and to gain an appreciation of the importance of fluids to life and our modern technological society.

This unit may be divided into topics such as the following:

- Characteristics of fluids
- Density, buoyancy, and pressure
- Archimedes' principle
- Pascal's principle
- Bernoulli's principle

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a realization of the important roles that fluids play in our society;
b) a curiosity about the properties and applications of fluids.

Skills. Students will have the opportunity to develop skill in:

a) recognizing practical applications of the properties of fluids, such as the use of a siphon (3b-3g);
b) measuring buoyant forces exerted by various liquids on the same object (2a, 8a, 8e);

c) experimentally confirming Archimedes' principle (2b, 8e);
d) drawing free-body diagrams to explain the position of floating, submerged, and sunken objects (2b, 8e);
e) applying Archimedes' principle, Pascal's principle, and Bernoulli's principle to practical situations or devices that employ fluid properties (2b, 2c, 3b, 3c, 3f, 3g);
f) using a barometer or a manometer (2e, 3d, 3e, 6a);
g) reproducing a theoretical derivation, such as proving that $p = \rho g h$ (2e);
h) solving mathematical problems involving density, relative density, pressure, Archimedes' principle, Pascal's principle, Bernoulli's principle in simplified form, and the equation of continuity, namely, $A_1 v_1 = A_2 v_2$ (5b, 8e).

Knowledge. Students will be expected to:

a) list various properties of fluids and compare different fluids with regard to some of their properties (2a, 6a);
b) define *density*, *pressure*, *relative density*, and *buoyancy* and identify the SI units in which they are measured;
c) distinguish between absolute pressure and gauge pressure;
d) state Archimedes' principle, Pascal's principle, and Bernoulli's principle and give examples to illustrate each one (2b-2d);
e) indicate how hydrostatic pressure is related to the depth and the density of a fluid (2e, 3d, 6a, 6b, 8b, 8c);
f) use a force diagram to analyse the forces acting on a submerged object that is hanging by a cord, on a floating object, and on a sunken object lying at the bottom of a body of water or other liquid (2b, 8e);
g) list several applications of fluid principles;
h) describe some careers that require an understanding of the behaviour of fluids;
i) identify some historically interesting facts about Archimedes, Pascal, or Bernoulli;
j) explain the operation of at least two of the following: a hydrometer, a barometer, a manometer, a siphon, a hydraulic lift;
k) explain the variations in pressure in an operating Venturi tube (2d).

2. Student Activities

Students are to:

*a) determine the buoyant forces exerted on an object that is successively immersed in several different liquids (6b, 8a);
*b) experimentally confirm Archimedes' principle for floating objects and for submerged objects that are suspended in liquids (8e);
c) confirm Pascal's principle by operating a simple hydraulic lever and examining its function (6c);
d) observe the differences in the pressure and speed of water as it flows through a Venturi tube;
*e) experimentally determine the relationships among the pressure, density, and depth of a liquid;
f) write a report on a topic related to fluids (e.g., medical or industrial applications).

3. Applications

a) Archimedes' principle can be used to determine the relative density of an unknown substance.
b) Buoyant forces act on ships, boats, submarines, deep-sea divers, swimmers, and fish. Such forces are described by Archimedes' principle.
c) People sometimes choose to exercise in water because its buoyant force helps to counterbalance the effect of gravity on the body.
d) Barometers are used to measure atmospheric pressure; this helps meteorologists in weather forecasting.
e) Doctors measure blood pressure with sphygmomanometers to assess the health of patients.
f) Hydraulic brakes, pumps, and presses make use of Pascal's principle.
g) Bernoulli's principle is used in devices such as atomizers, paint sprayers, and carburetors.

---

*See the subsection entitled "Student Activities" on page 5.

4. Societal Implications

a) Transportation by air and water has contributed to converting the world to a global village.
b) Water towers benefit millions of people by providing water at high pressure for use in homes, industry, firefighting, and recreation.
c) Hydraulic presses perform manufacturing tasks that would be impossible to do manually. The use of hydraulics in cars, planes, factories, and farm equipment has made life easier for many people.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) laboratory experiments and reports, science notes, and oral communication;
b) explanations of applications based on scientific principles that apply to fluids;
c) problem solving that includes the use of physics equations and principles.

6. Safety Considerations

a) Students are not to use mercury in its elemental form.
b) Students are to be fully aware of the chemical hazards of all fluids used.
c) Very high and very low pressures in some laboratory equipment, such as simple hydraulic presses and vacuum tubes, may result in situations where students are in danger. Caution should be taken to ensure their safety.

7. Possible Extensions

Some students might:

a) conduct investigations to study the surface tension of several liquids;
b) investigate the phenomenon of capillary action;
c) measure the speed of objects (e.g., marbles, ball bearings) falling through liquids that have different densities and viscosities and then devise related hypotheses;
d) determine the speed of water flowing through a tube, given its internal diameter or area and the time it takes to collect a measured amount of water discharged by the tube (e.g., What is the speed of water flowing through a hose that has an internal cross-sectional area of 2.0 cm^2 when 4.5 L of water are discharged from the hose in 1.5 min?);
e) read about airflow around an airplane wing or a car body and write a report on airflow and its implications in airplane or car design;
f) visit a garage, farm, or factory to observe uses of hydraulic equipment.

8. Some Teaching Suggestions

a) In activity 2a a weighted wood stick of uniform cross section or a hydrometer may be used in a variety of liquids or in salt or sugar solutions having different concentrations.
b) In activity 2e a pressure transducer connected to a computer with the output displayed on the screen of a cathode ray tube can provide an interesting demonstration of the equality of pressure in all directions at a given depth.
c) A tin can with holes drilled at different heights and filled with water will show the relationship between various depths and pressures and can be used to determine how the speed of the water jets is related to the height of water above the holes.
d) To demonstrate how the pressure at a point in a liquid is related to its density and depth at the point, water can be poured into a U-tube, and then an equal volume of oil can be poured into one side only. The liquids will reach an equilibrium, with the oil having the higher surface level.
e) All forces in free-body diagrams should be indicated in newtons; such diagrams should be used to illustrate experimental data as well as solutions to appropriate mathematical problems.

Optional Unit 3

Thermal Energy

Time: 10 hours

The study and application of thermal energy associated with the motion of atoms and molecules continue to have important ramifications for society. Heat maintains life, assists in the preparation of food, is involved in the growth and activity of humans, is essential to industry and transportation systems, and can be converted to other forms of energy such as light and electricity. In this unit the study of the characteristics of thermal energy is an extension of the studies on heat in the advanced-level Grade 10 science course.

This unit may be divided into topics such as the following:

- The kinetic-molecular theory
- Heat and temperature
- Specific heat capacity
- Latent heats of fusion and vaporization
- Thermal expansion

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a concern about the wise use of energy (4a, 4d);
b) an appreciation for the scientific method as a means of answering questions (2c, 4c);
c) a realization of the important role that thermal energy plays in our society (3, 4).

Skills. Students will have the opportunity to develop skill in:

a) experimenting quantitatively with the aid of a calorimeter (2a-2c);
b) *designing* an experiment (2c);
c) solving problems involving heat exchange, changes of state, and thermal expansion using the following relationships: $Q = mc\Delta T$, $Q = ml_f$, $Q = ml_v$, $\Delta L = \alpha L\Delta T$, $\Delta V = \beta V\Delta T$ (5c);
d) applying the kinetic-molecular theory to explain phenomena such as heating, thermal expansion, specific heat, and changes of state (5d).

Knowledge. Students will be expected to:

a) define *heat*, *temperature*, and *thermal energy* and differentiate among them (8b);
b) state the main postulates of the kinetic-molecular theory (8b);
c) know the three factors that affect the quantity of thermal energy gained or lost by a substance and state how each factor affects that quantity (8b);
d) define the following terms: specific heat capacity, latent heat of fusion, latent heat of vaporization, coefficient of linear expansion, coefficient of volume expansion;
e) describe (but not necessarily explain) the "abnormal" behaviour of water and stretched rubber in regard to expansion and contraction when these substances are heated (8f);
f) describe situations in which thermal expansion must be taken into account (3c).

2. Student Activities

Students are to:

*a) determine, by the method of mixtures, the specific heat capacity of one or more substances (8d);
*b) determine experimentally the latent heat of fusion of water;
c) *design* and perform a laboratory experiment to find the latent heat of vaporization of water (5a, 8c, 8d);
*d) determine the linear coefficient of expansion of a metal;
e) experimentally find the volume coefficient for the expansion of a liquid such as alcohol;
f) write a report on the structure and physical principles behind the operation of a device that employs thermal energy.

3. Applications

a) Water has a moderating effect on air temperatures near large lakes and oceans because of its high specific heat capacity.
b) The transfer of a large amount of heat energy when steam condenses on the skin can cause severe burns.
c) Thermal expansion is used in thermostats to regulate room temperatures and must be considered in the design of buildings, bridges, railways, and highways.

---

*See the subsection entitled "Student Activities" on page 5.

4. Societal Implications

a) Thermal energy is frequently wasted in manufacturing processes and electrical energy production and can cause thermal pollution of the environment, particularly of bodies of water.
b) A tremendous amount of energy is used in North America to heat our homes and workplaces in winter and to cool them in summer.
c) New, imaginative heating and cooling systems are being developed to reduce our need for fossil fuels and nuclear energy.
d) The wise use of energy is important because the supply of conventional fossil fuels is dwindling and the use of nuclear fuels is still a controversial issue.
e) An understanding of thermal physics is useful in employment involving food processing, dietetics, refrigeration, home heating, metallurgical refining and processing, construction, architecture, and engineering.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) experimental techniques;
b) laboratory reports;
c) problem solving;
d) explanations involving the use of the kinetic-molecular theory.

6. Safety Considerations

a) All necessary precautions should be taken to avoid burns when steam, hot liquids, and hot containers are being used.
b) Any buildup of steam or hot vapours must be avoided.
c) Electrical heating devices should be industrially approved and should be regularly checked to ensure that components have not been damaged and have not deteriorated.

7. Possible Extensions

Some students might:

a) study prepared temperature-time graphs of heating curves showing changes of state for several pure substances and compare such graphs with one for water;
b) determine the specific heat capacities of some fluids other than water (e.g., ethylene glycol);
c) investigate the insulation values of various commercially available home-insulation materials and compare the costs of materials having similar R-factors;
d) construct simple solar heaters for the passive heating of water and experiment with several variations in construction materials to determine the optimum material;
e) investigate the possibilities of building subterranean homes to save on insulation in both the summer and the winter;
f) discuss the laws of thermodynamics and relate the first law to the law of conservation of energy;
g) report on Sadi Carnot's work, specifically in regard to the limitations in converting heat energy into mechanical energy in internal-combustion engines, steam turbines in thermal-electrical power plants, and so on.

8. Some Teaching Suggestions

a) Recommended symbols and preferred SI units for use in this unit are listed in Appendix B in Part 1 of the guideline.
b) Some review of the Grade 10 unit on heat may be necessary for some students.
c) In activity 2c students should be encouraged to select their own apparatus and to design their own procedure. They should be permitted to use their own ideas despite their limitations, provided that safety considerations have been taken into account. Students must be aware of the danger of burns and accidents that can be caused by steam.
d) Experimental calculations and heat-exchange problems should take into account the specific heat capacity and mass of the calorimeter.
e) Computer software is currently available to simulate heat-transfer experiments, to explain the kinetic-molecular theory, and to review the basic properties of heat and thermodynamics. However, computer simulations are not to replace student activities that can be carried out through a laboratory experience.
f) The anomalous behaviour of water, which contracts when heated from 0°C to 4°C, should illustrate the problem of rigid adherence to a theory. Also, it may be shown that while unstretched rubber expands when heated, stretched rubber contracts. Explanations of such apparent contradictions to the kinetic-molecular theory are not required in this course. However, students should realize that theories may have limitations and may require revision.

Optional Unit 4

Locally Designed Unit

Time: 10 hours

This unit is to be designed at the local level as desired. It can be used (a) to introduce a new area of physics that is not described in this guideline, (b) to incorporate additional objectives that will expand a previous part or parts of the course, or (c) to reinforce various aspects of the core units that may require greater emphasis. The following are examples of new areas or topics that might be considered:

- Alternating-current circuits
- Basic electronics
- Colour
- Graphical analysis
- Interference of waves
- Machines
- Physical properties of matter
- Physics of the human body
- Physics in society
- Solid-state physics

Consideration might be given to providing for a change in approach or emphasis. For example, the unit could focus on "Industry and Society" in a manner similar to that followed in core unit 7 of Chemistry, Grade 11, Advanced Level. This unit may also provide an excellent opportunity for students to engage in independent study on a topic in physics. Such a study should be approved, monitored, and evaluated by the teacher. Topics from the physics OAC are to be avoided, however.

A locally designed unit is to incorporate components similar to those adopted in the core units, namely, objectives, student activities, applications, societal implications, and safety considerations. A description of the unit is to be included with the school's course outline and kept on file so that it is available to interested students and parents.

Physics, OAC
(SPH0A)

Core Units

Kinematics
Dynamics
Momentum and Energy
Electrostatics
Waves and Light
Early Quantum Theory

(90 hours)

Optional Units

Special Relativity
Bodies in Equilibrium
Electromagnetic Radiation
Elementary Particles
Locally Designed Unit

(20 hours)

Core Unit 1

Kinematics

Time: 19 hours

Motion has intrigued people for centuries. The flight of a bird, the circulation of blood, the transmission of heat, the blast of the wind, the rush of traffic, the flow of electricity, the movement of satellites, the vibrations of atoms and molecules, and the emission of particles from radioactive materials all involve basic concepts of motion. The purpose of this unit is to help students describe straight-line, circular, and projectile motion and to analyse these motions in terms of fundamental concepts.

This unit may be divided into topics such as the following:

- Motion with constant velocity
- Motion with constant acceleration
- Vector analysis of motion
- Projectile motion
- Circular motion

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the fact that everything in the environment is or can be in motion (3, 4);
b) an interest in applications of principles of projectile motion in everyday life, for example, in sports (4b);
c) an appreciation of the fact that a few simple laws of physics explain a great variety of phenomena involving linear, projectile, and circular motion (3d);
d) an interest in the fact that several areas of employment are involved in the study, development, and monitoring of motion (4f).

Skills. Students will have the opportunity to develop skill in:

a) conducting experiments involving straight-line acceleration, projectile motion, and circular motion in order to analyse the characteristics of the motion under study (2a-2c);
b) interpreting graphical representations of motion, the slopes of tangents to displacement-time and velocity-time graphs, and the areas underneath velocity-time graphs (2a);
c) determining velocity by calculating the slope of a displacement-time graph both for a particular instant of time and for a given interval of time (2a);
d) determining displacement by calculating the area underneath a line segment for a given interval of time on a velocity-time graph (2a);
e) determining acceleration by calculating the slope of a velocity-time graph both for a particular instant of time and for a given interval of time (2a);
f) analysing a velocity-time graph, where the acceleration is constant and not equal to zero, in order to derive the equation $s = ut + \frac{1}{2}at^2$ and identify ut and $\frac{1}{2}at^2$ on the graph as areas that represent displacement (2a);
g) deriving equations from first principles (5c, 8d);
h) solving mathematical problems and showing full solutions involving the following equations: $v = u + at$, $s = \frac{1}{2}(u + v)t$, $s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2ad$, including cases in which the acceleration is that resulting from gravity (2a, 5b);
i) drawing scale diagrams to solve vector problems (2b, 5b);
j) resolving a vector into rectangular components and showing that such components are mutually independent (2b, 5b);
k) solving vector problems using trigonometry (2b, 5b);
l) solving problems on relative motion in one and two dimensions, such as river-crossing problems that combine the velocity of a boat relative to the water with that of the water relative to the land (5b);
m) identifying the components of projectile motion by associating horizontal motion with constant velocity and vertical motion with constant acceleration, and then solving related problems (2c, 5b);
n) determining answers to problems on the kinematics of circular motion involving constant speed and the equations $v = 2\pi r/T$ and $a_c = v^2/r$, where a_c is centripetal acceleration (2c, 5b).

Knowledge. Students will be expected to:

a) distinguish among kinematics, dynamics, and mechanics;
b) review the meanings of the following terms and indicate their interrelationships: distance and displacement; uniform motion; average speed, velocity, and acceleration; instantaneous speed, velocity, and acceleration;
c) analyse situations in which displacement, velocity, and acceleration are involved and solve relevant problems (2a, 5b);

d) define the following terms as they apply to circular motion: period, frequency, speed, instantaneous velocity, centripetal acceleration (2c);
e) relate speed to frequency or period for circular motion;
f) explain why an object travelling in a circle at a constant speed accelerates;
g) state the directions of the instantaneous velocity and acceleration of an object undergoing circular motion at constant speed;
h) analyse the horizontal and vertical components of projectile motion in order to solve problems (2b, 5b).

2. Student Activities

Students are to:

*a) determine the constant acceleration of an object moving in a straight line and analyse such motion by means of graphs (8a);
*b) investigate the independence of the vertical and horizontal components of velocity in projectile motion;
c) determine the period, frequency, speed, and acceleration of an object undergoing circular motion at a constant speed (6b, 6c).

3. Applications

a) Speed limits have become an important controlling mechanism in traffic flow and human behaviour.
b) With the assistance of computers, public transportation companies can monitor the motion of vehicles and analyse traffic-flow problems.
c) The principles of circular motion have been applied in the workings of certain amusement-park rides (e.g., the roller coaster, Ferris wheel, merry-go-round).
d) By noting and studying motion, early observers were able to predict the paths of some planets and then discover their existence (e.g., Neptune was discovered through Adam's and Leverrier's prediction, Pluto through Lowell's prediction).

4. Societal Implications

a) Kinematics can be and has been used to predict accurately the motion of bullets, rockets, and missiles.
b) A basic understanding of projectile motion is important to an athlete who wants to excel in certain sports or to a pilot who wishes to drop medical supplies in remote or troubled regions.
c) Relatively recent studies of the motion of humans in sports have led to improved athletic performance. Such studies are included in a branch of science called *biomechanics*.
d) Circular motion and other forms of non-linear motion can provide interest and excitement (e.g., rides at amusement parks).
e) The principles of circular motion were applied to the early models of the atom by Rutherford and Bohr.
f) Careers in which the study or monitoring of motion occurs include the work of traffic-control officers; urban planners; amateur and professional athletes; coaches; paid competitors in car-, boat-, and horse-racing events; designers of machinery; game hunters; crane operators; acrobats; flight controllers; ballistics experts; scientists engaged in biomechanics and kinesiology; engineers; astronomers; air-traffic controllers; flight navigators; and astronauts.

5. Evaluation of Student Achievement

At least 60 per cent of the term mark for this unit is to be based on students':

a) laboratory experiments, precision in measuring, graphical skills, and laboratory reports;
b) mathematical problem solving involving full solutions, graphical analysis, and vector diagrams;
c) derivation of equations from first principles.

6. Safety Considerations

a) If an air table or air track with a high-voltage sparking system is used, students must be instructed in the proper use of, and the safety considerations related to, the equipment.
b) When any experiment involving objects travelling in circles is conducted, care must be taken to allow plenty of room between students to prevent anyone from suffering injury.
c) If a demonstration is made of a device that rotates at high speed, students must be warned that they are not to be in line with the plane in which the circle of rotation is located.

7. Possible Extensions

Some students might:

a) investigate Kepler's laws (8e);
b) measure the acceleration resulting from gravity, using various techniques, including one that involves a pendulum;
c) study the motion of an object in which the magnitude of the acceleration changes;
d) study some of the topics that are based on rotational motion, such as angular velocity and angular acceleration.

---

*See the subsection entitled "Student Activities" on page 5.

8. Some Teaching Suggestions

a) The importance of making the most precise measurement allowed by an instrument should be stressed.
b) Students should be able to recognize accelerated motion as motion in which (i) the magnitude of the velocity changes without change in direction; or (ii) the direction of the velocity changes without a change in its magnitude; or (iii) both the magnitude and the direction of the velocity change.
c) When timing short events, such as the period of a small object at the end of a string being whirled round in circles, students should know how to reduce the human error in the measurement of the time elapsed.
d) Students should be expected to follow derivations of the equations that they are expected to use and know. Several equations should be identified as ones that students should be able to develop from first principles.
e) One way to have students investigate Kepler's laws would be to have them list the planets and their periods. Then, given the distance from the sun to one of the planets, they can determine the distances to all of the others by means of Kepler's third law. The calculated results could then be compared with the actual values for the planetary distances.

Core Unit 2

Dynamics

Time: 19 hours

Dynamics is the portion of mechanics that describes why things move as they do. An understanding of the principles of dynamics will permit students to examine the forces that cause changes in motion or maintain uniform motion. Students will learn a few simple laws of physics that describe the forces that influence complex motion.

This unit may be divided into topics such as the following:

- Proportional relationships
- Newton's laws of motion
- Vector analysis of forces
- The law of universal gravitation
- Centripetal force
- Weightlessness
- Inertial and non-inertial frames of reference

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the fact that the laws of motion can be used to simplify descriptions of apparently complex motions (3a, 3c, 3d, 3f);
b) a respect for the ability of mathematics to aid in describing motion and its cause (3b, 3f);
c) a curiosity in areas of technology and engineering that require an understanding of the interrelationships between force and motion (3a-3e);
d) an interest in the application of classical physics to modern technology, such as the launching of satellites (3c, 4e).

Skills. Students will have the opportunity to develop skill in:

a) drawing scale diagrams to find resultant forces or vector components;
b) solving vector force problems using trigonometry, including the sine and cosine laws (5b);
c) adding and subtracting vector forces and resolving forces into mutually perpendicular components (5b);
d) conducting investigations into Newton's laws of motion (2a-2c);
e) tabulating, graphing, and analysing data obtained from investigations (2a-2d, 8g);
f) determining a relationship between variables by analysing a graph (2a, 8g);
g) recognizing the general shape of a graph of two quantities that are related by inverse proportion (2a, 8d, 8g);
h) determining an equation involving variables that are related by inverse proportion by plotting these items (e.g., acceleration a against reciprocal mass $1/m$) on a graph and finding the slope (2a, 8g);
i) identifying the nature of the centripetal force in various physical situations (8h);
j) constructing graphs that illustrate how various factors (e.g., frequency, period, speed, radius) are related to the centripetal force that acts on an object that moves in a circle at constant speed (2d, 3e);
k) solving problems involving Newton's laws of motion; the equations used in such problems may include those used in Kinematics as well as the following: $\sum F = F1 + F2 + F3 + ...$; $F = ma$; $F_c = ma_c$, where the subscript "c" denotes *centripetal*; $F_g = mg$; $F_{\text{by A on B}} = F_{\text{by B on A}}$ (2a-2c, 5b);
l) solving problems using the universal law of gravitation and deriving the units of G (5b).

Knowledge. Students will be expected to:

a) state the mathematical meaning of *inverse proportion* (2a, 5b);
b) determine an equation from a table of values for two variable quantities that are related by an inverse-square proportion, for example, $F_c \propto 1/T^2$ or $F_g \propto 1/r^2$ (8g);
c) define *frictional force* and *coefficient of friction*;
d) distinguish between static and kinetic friction;
e) state Newton's three laws of motion;
f) give examples of pairs of action and reaction forces, stating, for each example, on what object and by what object each of the two forces is exerted;
g) apply Newton's laws of motion to problems involving single and multiple forces (5b);
h) draw free-body force diagrams (5b, 8c);
i) use Newton's laws of motion to describe what would happen in various situations where forces exist;
j) state the law of universal gravitation in sentence and in mathematical form;
k) distinguish between the terms *mass* and *weight* and determine the weight of a given mass (*note*: since the term *weight* has different meanings in everyday life and science, it is preferable to use the expression *force of gravity* in lieu of *weight* in physics; see footnotes 17 and 20 to the table in Appendix B on page 85 of Part 1 of the guideline);
l) know and work with the equations for centripetal acceleration and force (2d, 5b);
m) realize that the centripetal force acting on a satellite is the force of gravity exerted by the central mass on the moving satellite (8h);
n) explain *weightlessness* in (i) an elevator that is falling freely and (ii) a spacecraft orbiting the earth (8f);
o) describe the conditions necessary for a satellite to follow a stable circular orbit and indicate the alternatives if such conditions do not exist;
p) explain why no work is done by the centripetal force acting on an object that moves in a circle at uniform speed (2d);
q) distinguish between an inertial and a non-inertial frame of reference (2e);
r) describe and explain the motion of a frictionless puck that is lowered gently onto a platform rotating at a uniform speed when the puck is viewed by a person (i) standing on the ground near the platform and (ii) sitting on the rotating platform (2e).

2. Student Activities

Students are to:

*a) plot a graph from a data table or from experimental data where two variables are inversely proportional and then determine the equation that relates the two variables (8g);
b) determine the net accelerating force that causes an object to accelerate down an inclined plane and verify that this is approximately equal to the object's mass times its acceleration (8e);
*c) verify Newton's second law (i) in the case where a block on a table is accelerated by means of a light string that passes over a pulley and is attached to a falling mass or (ii) by using an Atwood machine (8e);
d) illustrate, by means of graphs, the relationships that exist between the centripetal force acting on an object moving in a circle at uniform speed and such factors as the frequency, period, speed, and radius of rotation (6b, 8g);

---

*See the subsection entitled "Student Activities" on page 5.

e) view the film *Frames of Reference* (if available), in which the basics of inertial and non-inertial frames are explored.

3. Applications

a) Newton's laws of motion explain the need for seat belts in cars and in aircraft.
b) The resolution of forces into components is a method commonly used to solve engineering problems.
c) Newton's second and third laws are involved in rocket launching (e.g., the space shuttle and jet travel).
d) Newton's third law is evident in track-and-field events, the operation of lawn sprinklers, the recoil of a rifle, a tug-of-war, sitting on a narrow rail, and opening a heavy door.
e) Forces involved in circular motion are applied, for example, to the following: wet clothes in a spin-dry washing machine, a child on a swing, particles in a centrifuge, passengers and cars travelling round a corner, satellites, planets, and rotating devices such as an electric grinding stone, the paddles in a mixer, or the blades in a blender.
f) The extension of the law of universal gravitation to the stars and galaxies has led to greater understanding of the workings of the universe.

4. Societal Implications

a) The debate over safety features in cars has led to much controversy about suitable legislation (e.g., Should air bags be mandatory?).
b) The decrease in air-travel times has helped to turn the world into a "global village".
c) The application of the laws of motion to the development of increasingly sophisticated machinery has reduced the need for physical labour and given people more leisure time.
d) Centrifuges assist analysts in separating out the components of many substances. Centrifuges have been used in research into proteins, blood, DNA, minerals, and other substances, which has led to discoveries and applications that have been of great benefit to humanity.
e) Modern communications are becoming increasingly dependent on satellite technology.
f) Apparent weightlessness in a spacecraft permits the carrying-out of some experiments that cannot be conducted readily on the earth. Such work is already opening up new frontiers for research and technology.

5. Evaluation of Student Achievement

At least 60 per cent of the term mark for this unit is to be based on students':

a) ability to perform and report on activities;
b) solutions of force problems involving vectors, free-body force diagrams, graphical analysis, Newton's laws of motion, centripetal forces, and gravitational forces.

6. Safety Considerations

a) If an air table or air track is used, students must be instructed in its proper operation to avoid electrical shock from the spark timer.
b) Ample room must be allowed between students who are experimenting with objects that are made to travel in circles.

7. Possible Extensions

Some students might:

a) test Newton's third law of motion by creating an explosion reaction between two spring-loaded carts;
b) read about the research and discoveries of Newton, Galileo, and Cavendish and present a seminar on them to the class;
c) analyse simple and complex machines (e.g., pulley combinations) and consider their mechanical advantage and efficiency;
d) determine the coefficients of static and kinetic friction between several materials by testing a variety of objects on different platforms;
e) study the forces involved when an object undergoes motion in a vertical circle when the object is at its lowest, highest, and mid-height points;
f) write a report, including the mathematical concepts involved, on the centripetal acceleration and forces involved in banked turns.

8. Some Teaching Suggestions

a) Some review of Grade 12 physics may be necessary, but no more than one hour in this unit should be allotted for such review.

b) Both scale diagrams and trigonometric calculations should be used to resolve vectors into components.

c) In free-body force diagrams, students should be able to identify *by what* and *on what* each force is applied.

d) The graph of an inverse proportion may be used to introduce the discussion of Newton's second law.

e) In student activities 2b and 2c, students should verify Newton's second law in different situations. Students will need to measure or determine masses, accelerations, and forces, including frictional forces. Complete free-body force diagrams should indicate the analysis of all forces involved.

f) Apparent weightlessness and true weightlessness are often confused. These terms should be explained to students, who should understand that an object's *weight* is the pull of gravity that it experiences because of the earth or other mass(es).

g) In this unit of study, students should become acquainted with a variety of graphs that illustrate different kinds of direct and inverse relationships in physics (e.g., $F \propto a$, $F_c \propto V^2$, $F_c \propto 1/r$, $F_g \propto 1/r^2$) and note the differences in the shapes of the graphs. The deriving of relationships and equations from tables of values and from graphs should also be included to some extent in this course, as time permits. However, an in-depth, rigorous treatment of graphical analysis is not required.

h) Students should recognize centripetal forces and realize that they are not separate from other natural forces, such as gravity, friction, and tension. For example, the centripetal force acting on a satellite in a circular orbit is just the force of gravity exerted by the central mass; the centripetal force acting on a car travelling round a flat circular curve is friction exerted by the road; and the centripetal force acting on a stone tied to the end of a string and moving round a circular path is the tension or pull of the string.

Core Unit 3

Momentum and Energy

Time: 16 hours

All moving objects have momentum and energy. When such objects collide or interact, momentum and energy are conserved. The purpose of this unit is to give students an appreciation of the laws of physics governing the transfer and conservation of such characteristics. The principles examined in this unit apply to particle physics, gas molecules, billiard balls, interactions in athletics, traffic collisions, meteoritic impacts, and a host of situations in which moving masses interact.

This unit may be divided into topics such as the following:

- Momentum and impulse
- The law of conservation of momentum
- Momentum in one and two dimensions
- Hooke's law
- Work and energy
- The law of conservation of energy

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the importance of the conservation of energy and momentum in the analysis of collisions between objects (3);

b) some interest in careers in technology and engineering that require an understanding of momentum and energy.

Skills. Students will have the opportunity to develop skill in:

a) measuring, tabulating data, and formulating generalizations while carrying out such experimental investigations as the following: (i) studying momentum changes in one- and two-dimensional collisions; (ii) studying energy changes during simple harmonic motion and during constant acceleration (2a, 2b, 2d);
b) *designing* an experimental technique to verify Hooke's law as applied to a spring (2c);
c) analysing graphs, for example, determining the work done by calculating the area under a graph of $F \cos \theta$ against d in cases where the force is variable (5b);
d) solving one- and two-dimensional problems involving collisions and explosions that are (i) elastic and (ii) inelastic (2a, 2b);
e) solving problems involving the following formulas: $F\Delta t = m\Delta v$, $p = mv$, $E = Fd \cos \theta$, $E_k = \frac{1}{2}mv^2$, $E_g = mgh$, $E_e = \frac{1}{2}kx^2$ (2d, 5b);
f) solving problems involving the principle of conservation of mechanical energy in a gravitational field by means of the formula $E_g = -Gm_1m_2/r$ (5b).

Knowledge. Students will be expected to:

a) define the following: momentum, impulse, isolated system, work, joule, kinetic energy, gravitational potential energy, elastic collision, inelastic collision, mechanical energy, elastic potential energy, binding energy, minimum escape velocity;
b) state the law of conservation of momentum, Hooke's law, and the law of conservation of energy;
c) understand that momentum is conserved in a collision or explosion, that is, that $\Delta p = 0$ (2a, 2b);
d) derive the formula $E_k = \frac{1}{2}mv^2$ from Newton's second law and the definition of *work*;
e) recognize that the change in kinetic energy of an object equals the sum of the work done by *all* the forces acting on the object (some work may be positive and some negative);
f) list at least three kinds of potential energy;
g) develop the formula $E_g = mgh$ for the gravitational potential energy of a given mass near the surface of the earth;
h) develop graphically the formula $E_e = \frac{1}{2}kx^2$ for the elastic potential energy stored in a spring (2d);
i) give examples of energy transformations involving more than one form of energy and solve related problems;
j) distinguish between elastic and inelastic collisions;
k) develop the formula $E_g = -Gm_1m_2/r$.

2. Student Activities

Students are to:

*a) investigate momentum and energy changes during a one-dimensional collision or mechanical explosion (8a);
b) investigate the momentum and energy changes during a two-dimensional collision (8a);
*c) *design* an experiment to determine the relationship between the force applied to a spring and the extension produced and then graph the data (5a);
d) investigate the energy transformations involved when a mass attached to a spring undergoes simple harmonic motion (8d);
e) compare experimentally the amount of work done on or by an object and the change in its kinetic energy when it undergoes constant acceleration (8b, 8e).

3. Applications

a) Examples of conservation of momentum include rocket propulsion, the recoil of a gun, a leap from a canoe, traffic collisions, the playing of billiards, the hitting of a tennis ball, the collisions of molecules, and dancing.
b) The concept of impulse is applied in the design of padded dashboards, retractable automobile bumpers, fire nets, trampolines, and ice-hockey sticks.
c) The principles of momentum and energy conservation are used in research into elementary particles.

4. Societal Implications

a) The increasing use of energy in contemporary society has led to research into and development of more efficient methods of energy transfer. For example, cars have become more fuel-efficient, smaller, more aerodynamically designed, and safer in the event of a collision.
b) The need for more energy has led to the development of new technologies involving the conversion of energy from the sun, wind, and tides. This activity has also provided new career opportunities.

5. Evaluation of Student Achievement

At least 40 per cent of the term mark is to be based on students':

a) performance of and reports on laboratory investigations;
b) solving of momentum, impulse, and energy-transfer problems.

---

*See the subsection entitled "Student Activities" on page 5.

6. Safety Considerations

a) Students must be instructed in the proper operation of an air table to avoid possible shock from its spark timer.
b) Students should be warned to exercise caution when using spring-loaded carts.

7. Possible Extensions

Some students might:

a) investigate the efficiency of energy transfer in one or more of the following situations: (i) a mass on a pendulum is drawn aside and allowed, first, to strike the spring of a cart and, second, to strike the flat end of the cart; (ii) a mass is dropped onto a nail that is embedded in different materials; (iii) a mass is raised by a motor to a certain height;
b) conduct experiments to further their understanding of simple harmonic motion;
c) present a report or seminar on alternative energy sources and their related technology.

8. Some Teaching Suggestions

a) Data obtained from developing Newton's second law can be used to discuss the concepts of impulse and momentum. The combination of Newton's second and third laws can be used mathematically to derive the law of conservation of momentum. Students should be provided with an opportunity to perform the mathematical derivation for the one-dimensional case after the completion of activity 2a.
b) Students may be divided into groups and assigned different experiments on the transformation and conservation of momentum and energy. Each group could then make generalizations from its results and report its findings to the class.
c) Wherever possible in problem-solving exercises, practical applications of energy transformations should be discussed, and practical, realistic situations used to illustrate the problems.
d) In student activity 2d, students should be challenged to design techniques for determining the elastic potential energy at maximum compression or elongation and also the maximum kinetic energy during the simple harmonic motion. It is intended that the treatment of simple harmonic motion be merely introductory and deal only with the transformation between potential and kinetic forms of energy.
e) In student activity 2e, students should try to devise their own technique. They should also comment on the effects of friction.

Core Unit 4

Electrostatics

Time: 12 hours

Only in the nineteenth century did physicists gain a clear understanding of electrical forces. Electrical communication systems are but one of the many practical applications based on this knowledge. This unit covers some of the basic concepts underlying electrical interactions in atomic physics, electromagnetic radiation, chemical reactions, and biological processes. It also illustrates the fact that the laws of mechanics apply to electric phenomena.

This unit may be divided into topics such as the following:

- Electric charges
- Electric force and Coulomb's law
- Electric fields
- Electric potential
- Motion of charged particles in an electric field
- Electric potential energy

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the fact that there are similarities in the nature of gravitational forces and electrical forces (3a, 8a);
b) an interest in the application of the laws of mechanics to electrical phenomena;
c) an appreciation that electrical forces are involved in biological and chemical processes, since such forces hold atoms and molecules together (3c);
d) an interest in the electrical aspects of careers in computer technology, communications, engineering, and biophysics (4c).

Skills. Students will have the opportunity to develop skill in:

a) constructing diagrams that illustrate invisible physical phenomena, such as electric field patterns (2b);
b) comparing and contrasting items such as electrical and gravitational forces and electrical and gravitational potential energies (2a);
c) predicting a formula based on analogy (e.g., the formula for electrical potential energy);
d) solving problems involving the following equations:
  - the magnitude of the electric force F exerted by a point charge Q at point B on another point charge q, situated at point A, which is at a distance r from point B, is $F = kqQ/r^2$;
  - the magnitude of the electric field (sometimes referred to as the magnitude of the electric field strength or intensity) at point A in the electric field is $\mathcal{E} = F/q = kQ/r^2$ (note that if the charge Q is positive, the vector direction of the electric field $\vec{\mathcal{E}}$ at point A is away from point B; if the charge Q is negative, the field $\vec{\mathcal{E}}$ at A is directed towards point B, that is, $\vec{\mathcal{E}} = \vec{F}/q$.);
  - the electric potential energy of either of the two point charges is $E_e = kqQ/r^2$;
  - the electric potential at point A in the electric field is $v = E_e/q = kQ/r$;
  - the electrical potential energy of the charge q at point A is $E_e = qV$;
  - the change in electric potential energy when a charge moves from one position to a second is $E_e = E_{e2} - E_{e1} = q(V_2 - V_1) = q\Delta V$ (2a, 5c, 8e);

e) determining the mass, speed, and energy of charged particles moving in a uniform electric field by applying the laws of mechanics, such as $\Delta E_k = \Delta\left(\frac{1}{2}mv^2\right) = Fd\cos\theta$ $= q\Delta V = \Delta E_e$ (2a, 5c, 5d, 8e);
f) solving problems requiring the application of unit analysis; for example, the unit of electric field strength may be either the newton per coulomb or the volt per metre, since they are equivalent (5b, 8e).

Knowledge. Students will be expected to:

a) state or explain the meaning of the following: law of conservation of charge, Coulomb's law, electric field, electric field strength, electric potential, potential difference, electric potential energy, electron volt (2a, 2b);
b) describe the electric field created by (i) a point charge, both positive and negative, (ii) two point charges, both like charges and unlike, and (iii) two oppositely charged parallel plates, including an indication of the high, moderate, and low points of the magnitude of such fields and which formulas are applicable to each field (2b);
c) summarize the properties of lines of force in regard to (i) their direction with respect to a positive test charge, (ii) where they begin and end, and (iii) their closeness as an indication of the magnitude of the field (2b);
d) express electric quantities in SI units (8e);
e) explain the electrostatic deflections of an electron beam in a cathode-ray tube;
f) describe examples of situations in which electric forces and fields play a significant role in their lives (3b, 3d).

2. Student Activities

Students are to:

a) determine the charge on an electron, using a Millikan oil-drop apparatus (6);
*b) investigate the electric field lines for different charge distributions, using an electric field mapping apparatus (6, 8a).

3. Applications

a) People can "feel" the effects of electric fields, particularly on dry, cold days, when they reach for a door handle in a carpeted room, comb their hair and bring the comb near some hairs on their arm, or pull a sweater off over their head.
b) Electrostatic fields are used in photocopy machines and in liquid crystal displays.
c) Chemical reactions and biological phenomena are dependent fundamentally on electric and thermal interactions of particles (e.g., the making and breaking of ionic, covalent, and hydrogen bonds; the formation of biological molecular structures such as muscle filaments and viruses).
d) Electronic air cleaners and electrostatic precipitators operate because of electric forces.
e) Cathode-ray tubes in oscilloscopes use electrostatic deflection for moving electrons. (Note that television sets and computer monitors use electromagnetic deflection.)

---

*See the subsection entitled "Student Activities" on page 5.

4. Societal Implications

a) Electrostatic effects in our daily lives can be both troublesome and useful. Computers must be grounded to protect sensitive components from electrostatic charges, and electrostatic precipitators are used to clean some emissions from coal-fired power plants.
b) High electric potentials that exist between transmission lines and the ground are dangerous.
c) A knowledge of electric charges, forces, energy interactions, and related phenomena is essential for the careers of many people engaged in communications, engineering, computer technology, and biophysics.

5. Evaluation of Student Achievement

At least 40 per cent of the term mark for this unit is to be based on students':

a) laboratory experiments or activities and related written reports;
b) solutions to non-numerical problems and notes made during independent study;
c) solutions to numerical problems related to electric phenomena only;
d) solutions to numerical problems that relate mechanics and electricity.

6. Safety Considerations

a) All wiring on electrical equipment must be checked to ensure that there are no frayed ends and that plugs are attached properly.
b) Students must be instructed in the safe and proper operation of electrical equipment, especially equipment involving high voltages.
c) Electrical equipment is not to be operated in an area where water is present.
d) Students are to be warned to turn off malfunctioning equipment and to report the problem immediately.

7. Possible Extensions

Some students might:

a) verify the inverse-square law of distance for the electric force between two charged objects;
b) determine the mass or charge-to-mass ratio of an electron;
c) study the role of electric interactions in some chemical reactions or biological processes;
d) explain the function of a capacitor, define *electric capacity*, and state the unit of capacitance.

8. Some Teaching Suggestions

a) It should be pointed out that a "field" is not a distribution of matter or energy or force. It is a region of influence identified by physicists to help analyse the physical world. It is a region that influences an object only when the object is placed within it.
b) Students should be assigned problems that emphasize and reinforce the basic concepts in this unit. All solutions to problems must include the appropriate units.
c) A Van de Graaff generator and pith-ball electroscopes or pith-ball compasses may be used to demonstrate the existence of electric field patterns.
d) A prediction of spot location by an electron beam on a screen can be made and then measured by using deflecting tubes and applying a known accelerating voltage.
e) Students should be aware of the coherent SI units for the physical quantities mentioned in this unit. They are as follows:
   - electric charge q or Q: coulomb (C)
   - electric force F: newton (N)
   - magnitude of electric field $\mathcal{E}$: newton per coulomb (N/C) or volt per metre (V/m)
   - distance or displacement r or d: metre (m)
   - electric potential energy E_e and kinetic energy E_k: joule (J)
   - electric potential V and potential difference ΔV: volt (V)
   - mass m: kilogram (kg)
   - speed or velocity v: metre per second (m/s)

   In terms of coherent SI units, Coulomb's constant $k = 9.00 \times 10^9\ \mathrm{N \cdot m^2/C^2}$.

Core Unit 5

Waves and Light

Time: 16 hours

Students of physics need to know about the characteristics of waves, sound, and light. In the Grade 12 physics course, students learned that sound transmission has a wavelike behaviour. Does light also behave like waves? In order to answer this, students will investigate wave characteristics and then see to what extent they are applicable to light.

This unit may be divided into topics such as the following:

- Characteristics and behaviour of waves
- Diffraction of light
- Interference of light
- Polarization
- Lasers

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the fact that scientific theories and models help explain and sometimes predict physical phenomena such as the behaviour of light (3c);
b) an interest in how physics has led to important technological advances in areas related to waves and light (4).

Skills. Students will have the opportunity to develop skill in:

a) investigating the effect of Polaroid filters on light (2f);
b) observing phenomena such as interference patterns produced by light and drawing diagrams to explain such patterns (2c-2e);
c) *designing* an experiment or investigation, for example, to determine the wavelength of light (2e);
d) comparing the characteristics of a flashlight beam and a laser beam (2g);
e) interpreting data from experiments such as polarization that illustrate the transverse wave nature of light (2f);
f) providing explanations by means of the wave model of light to account for various characteristics of light (2b, 2c);
g) solving problems involving the following formulas:

- the speed of a wave, $v = f\lambda$;
- $d \sin\theta = m\lambda$ for a diffraction grating pattern or for constructive double-slit interference, where $m = 0, 1, 2, \ldots$; and $d \sin\theta = (m - \frac{1}{2})\lambda$ for destructive interference, where $m = 1, 2, 3, \ldots$ (note that m is used here to denote the number of each bright or dark interference fringe, because n is used in some interference equations to denote an index of refraction);
- the separation between bright fringes for double-slit interference, $\Delta x = L\lambda/d$;
- single-slit diffraction, $w \sin\theta = m\lambda$, where w is the width of the slit and minimum intensity occurs for $m = 1, 2, 3, \ldots$;
- interference in a thin film, $2nt = m\lambda$, when the reflected intensity is a minimum and $2nt = (m + \frac{1}{2})\lambda$, when it is a maximum, where t is the thickness of the film at the point of interference being considered, n is the film's refractive index, and $m = 0, 1, 2, \ldots$ for the minimum or the maximum fringes (2a, 2c, 2e, 5b).

Knowledge. Students will be expected to:

a) define or explain the following terms: vibration, amplitude, period, frequency, wavelength, plane-polarized light, diffraction, constructive and destructive interference;
b) distinguish between energy transmission by particles and by waves (2a);
c) distinguish between transverse and longitudinal waves (2a);
d) use the principle of superposition to determine the resultant displacement when two waves interact (2d);

e) describe the apparatus designed by Thomas Young to produce interference of light from two point sources (2d);
f) derive the equations for the constructive and destructive interference of light for double-slit interference (2e);
g) describe the function and operation of Polaroid filters, including sunglasses (2f);
h) explain how Polaroid filters demonstrate the transverse wave nature of light (2f);
i) describe four wavelike properties of light: reflection, refraction, diffraction, and interference;
j) describe the diffraction pattern of monochromatic light passing through single slits of various widths and develop a related equation (2b);
k) describe how interference in thin films may produce both constructive and destructive interference, and develop a related equation (2c);
l) identify and understand the differences in the intensity, coherence, and divergence of light from an ordinary light source and from a laser (2g);
m) describe at least two applications of lasers (3e).

2. Student Activities

At least one activity should be selected to fulfil skill objective (c), which requires students to *design* an experiment or investigation. Students are to:

a) measure the frequency and wavelength of water waves and then determine the speed of the waves;
b) investigate the phenomena of single-slit diffraction with water waves and with light (5b);
*c) determine the thickness of a hair or a piece of paper, using the principles of interference in thin films (5b);
*d) observe the interference pattern for double-slit interference in water waves and the effects of wavelength and slit separation on the number and location of nodal lines, and draw the pattern observed for the double-slit interference of light and a diagram to show how the sets of wave fronts interact (5a);
*e) determine the wavelength of monochromatic light from a double-slit interference pattern or a diffraction grating pattern (5b);
*f) investigate the effect of one and two Polaroid filters and sunglasses on light (6a);
g) compare the coherence, intensity, and divergence of a beam of light from an incandescent source and a laser (6b, 8a).

3. Applications

a) Diffraction gratings are used in some spectrometers to analyse light emitted or absorbed in physical reactions.
b) Polaroid sunglasses and Polaroid camera filters reduce glare when light is reflected.
c) Certain solutions of substances such as sugar, insulin, and collagen polarize light. Polarization has enabled scientists to obtain much information on the shape and properties of molecules in such solutions.
d) Thin films are used to reduce glare and improve light transmission in the optical lenses in cameras and eyeglasses. Some thin films produce almost total reflection and give the "mirror" appearance of some sunglasses.
e) Lasers are finding many applications in the health-care field, for example, in the treatment of cancer and in eye surgery.
f) The straightness and intensity of a laser beam make it useful for surveying, particularly in inaccessible areas, such as those encountered in underwater and underground situations.

4. Societal Implications

a) Laser surgery has improved the quality of life for many people suffering from problems such as cancer and eye defects.
b) Holography is opening up new frontiers in science that may affect our lives. Possibilities exist in such areas as holographic microscopy, which may enable the examination of the interior of the eye or brain; non-visible radiation analysis of nucleic acids and proteins; acoustical examination of the shape and placement of internal organs of a body; and perhaps truly three-dimensional movies.
c) Interferometers, instruments that operate on the principle of interference of light, permit great accuracy in measuring very small lengths.
d) Many careers require a knowledge of the behaviour of light and related phenomena such as colour and laser beams.

---

*See the subsection entitled "Student Activities" on page 5.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark is to be based on students':

a) drawing of an interference pattern for double-slit interference, given the wavelength and slit separation;
b) solving of problems involving equations for single-slit, double-slit, and thin-film interference;
c) experimental design and laboratory work and reports.

6. Safety Considerations

a) Students are to be warned not to look directly at the sun through Polaroid or any other sunglasses.
b) In the setting-up of a laser experiment, precautions must be taken to ensure that students do not look directly into the beam. The teacher should guard against the possibility of the laser beam being reflected off shiny surfaces into students' eyes.

7. Possible Extensions

Some students might:

a) write a report on Huygens's work on optics or Young's work on the theory of waves;
b) compare the diffraction and interference patterns of waves and light;
c) observe and explain the effects produced by diffraction gratings;
d) study various reflective coatings on lenses and mirrors;
e) investigate the Doppler effect.

8. Some Teaching Suggestions

a) The flashlight used in activity 2g to compare the intensity and divergence of the light beams should be covered with black paper, in which there is a hole the size of the aperture of the laser.
b) If the school does not have a laser, a visitor from a university, a college, or industry could be invited to the class to demonstrate the operation of a laser and to discuss applications of lasers.
c) Field trips to local industries, hospitals, or businesses that use lasers might be arranged for students.

Core Unit 6

Early Quantum Theory

Time: 8 hours

In this century our understanding of the behaviour of energy and matter has been irrevocably altered by the quantum theory. The story of how this theory was developed and gained acceptance by the scientific community exemplifies the nature of the scientific enterprise.

This unit is intended to give students a basic knowledge of what this theory entails and to help them realize that scientific progress depends on the willingness of individuals to support concepts tentatively even before they have been verified empirically. The quantum theory demonstrates the error of extrapolating from macroscopic experiences and laws to the atomic and subatomic level.

This unit may be divided into topics such as the following:

- The photoelectric effect
- The Compton effect
- Photon interactions and pair production
- Wave-particle duality
- Photon momentum
- The wave nature of matter

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the fact that scientific models, such as the wave model of light, help explain the real world, but that they also have limitations (3b, 4c);
b) an appreciation for the fact that physics is a human activity, a growing, changing subject, and not simply a collection of facts or static theories (3a, 4c);
c) a willingness to experience new ways of thinking about the physical world and to understand concepts that appear illogical and that contradict our perception of the world;
d) an interest in applications of the quantum theory to careers in such areas as research, atomic physics, and engineering (4d).

Skills. Students will have the opportunity to develop skill in:

a) observing the photoelectric effect and interpreting results from experiments on the photoelectric effect (2a, 6b);
b) comparing the photoelectric and Compton effects (2a, 6b);
c) reading and organizing material for seminars or presentations on topics related to the work of a scientist who contributed to the quantum theory (2c);
d) solving problems involving the following equations:
  - ▸ $E = hf$ for quantized energy of a photon;
  - ▸ $E_k = hf - W$, the photoelectric equation;
  - ▸ $p = E/c = hf/c = h/\lambda$ for photon momentum;
  - ▸ $\lambda = h/mv$, the de Broglie wave equation for matter (2a, 5b).

Knowledge. Students will be expected to:

a) explain the meaning of the following terms: quantum and quanta, photon, photoelectric effect, work function, photoelectron, wave-particle duality, pair production, positron, matter waves, de Broglie wavelength;
b) list several examples of quantization;
c) describe the conditions necessary for photoelectric emission (2a);
d) describe the relationships among the number of photoelectrons emitted, their energy, the material of the photocathode, and the intensity and wavelength of light for the photoelectric effect (2a);
e) use the photon concept to interpret the photoelectric effect (2a);
f) explain the meaning of each term in the photoelectric equation (2a);
g) describe at least two applications of the photoelectric effect (2b);
h) describe the Compton effect, identify the conditions under which it occurs, and realize its significance in supporting the theory that light at times appears to have a particlelike behaviour (2a);
i) list the experimental evidence supporting some of the particle characteristics of light (2a, 2c);
j) understand that light appears to have two complementary aspects in its behaviour; it sometimes acts as waves and sometimes as particles;
k) realize that a photon travels at the speed of light and has a momentum, $p = E/c = hf/c = h/\lambda$ (2c);
l) describe three ways in which a photon can interact with matter, namely, by the photoelectric effect, the Compton effect, and pair production;
m) outline experimental evidence from the Davisson-Germer experiment for the wave nature of matter;
n) state the de Broglie wave equation for matter waves.

2. Student Activities

Students are to:

*a) observe the following:
  - ▸ the effect of radiation from an unshielded arc lamp falling on a negatively charged zinc plate that is connected to an electroscope;
  - ▸ the effects of shielding the arc lamp with glass and of charging the zinc plate positively rather than negatively;
  - ▸ the effects of various incident wavelengths of radiation on a photoelectric surface;
  - ▸ the effect of increasing the light intensity on a current produced by electron emission from a photoelectric surface (6a, 6b, 8a);

b) demonstrate and explain at least one application of the use of the photoelectric effect, for example, burglar alarms, automatic door openers, smoke detectors (8a);
*c) make a presentation on the various contributions of the following scientists to the development of the early quantum theory (8a):
  - ▸ Planck
  - ▸ Einstein
  - ▸ Compton
  - ▸ Bohr
  - ▸ de Broglie
  - ▸ Davisson and Germer
  - ▸ Pauli
  - ▸ Schroedinger
  - ▸ Heisenberg
  - ▸ Franck and Hertz
  - ▸ Millikan
  - ▸ Bragg

---

*See the subsection entitled "Student Activities" on page 5.

3. Applications

a) Photoelectric cells are used in various ways (e.g., in automatic door openers, burglar alarms, smoke detectors, photographic light meters, spectrophotometers). However, for many applications today the vacuum-tube photocell has been replaced by the photodiode.
b) High-energy photons interact by means of the photoelectric effect, the Compton effect, and pair production wherever there is matter (e.g., in the sun, our bodies, our homes); in radiation detectors, these interactions are used to produce a detectable electric current.

4. Societal Implications

a) The vocabulary of quantum physics has become part of the vernacular (e.g., quantum leap).
b) Research in many areas of modern physics may require sophisticated and sometimes costly equipment. Funding is often a political activity involving universities, industries, and governments.
c) Many aspects of the quantum theory have led to technological advances that have benefited society (e.g., the electron microscope, the laser, semiconductors, and computers).
d) Many careers in scientific research and all careers in applied atomic physics require some understanding of the quantum theory.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) successful completion of student activities 2b and 2c;
b) solving of problems involving the equations mentioned in this unit.

6. Safety Considerations

a) When students are organizing and performing demonstrations, there must be a careful check to ensure that the set-ups are safe before they are operated.
b) In order to avoid serious eye damage, students must be warned not to look directly at the beam produced by an arc lamp or a laser.
c) Students should be given clear instructions about the use of microammeters if they are needed for the work outlined under "Possible Extensions".

7. Possible Extensions

Some students might:

a) investigate the theory of black-body radiation, including Planck's quantum theory and Wien's law;
b) investigate the cut-off potential for a given photocell by assembling the apparatus, measuring the values, and plotting a graph to show the results obtained;
c) investigate the theory and applications of X-ray diffraction.

8. Some Teaching Suggestions

a) Since the equipment needed for the student activities in this unit is specialized, it is recommended that demonstrations be given by students. Demonstrations of laboratory activities and presentations of acquired information should give students experience in gathering data and communicating their findings to others. If a class is small, some students may work singly, but students should have the opportunity to work in groups so that they can display co-operative effort. Each group should share its findings with the class so that each student need not actually perform all components of mandatory activities 2a and 2c.
b) It is important for students to understand that it is not possible to represent all physical phenomena by a single model. Students should realize that physicists seek to create conceptual models (e.g., the wave-particle duality model) in an attempt to explain physical phenomena.
c) Speakers may be invited from a university or industry to present a lecture on one of the topics in the unit.
d) A field trip may be arranged for students to see an electron microscope, tandem accelerator, nuclear reactor, or other applications of modern physics in operation.

Optional Unit 1

Special Relativity

*Time: 7 or 10 hours**

The speed of light in a vacuum is a constant regardless of the speed of the light source or of the observer. With this postulate, Albert Einstein predicted that as an observer's speed approached the speed of light, time dilation, length contraction, and an increase in mass would occur. All these predictions have been experimentally confirmed. Einstein opened our thinking and has encouraged our minds to be flexible enough to accept ideas that seem contradictory but are scientifically sound.

The purpose of this unit is to introduce students to some premises, postulates, and ramifications of the theory of special relativity and to prepare them for the mental flexibility and dexterity that they will need to deal with new knowledge and thinking patterns. The ability to adapt readily to new modes of thinking and living will continue to be pivotal to students' success in life management.

This unit may be divided into topics such as the following:

- Inertial frames of reference: Galilean transformations
- Principles of special relativity
- Time dilation
- Length contraction
- Mass increase
- Equivalence of mass and energy

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the fact that scientific information and premises for logical scientific deductions can be obtained by various techniques, including "thought experiments";
b) a realization that facts that form the basis for scientific deduction are those that have been verified and yet are open to continued testing (3b).

Skills. Students will have the opportunity to develop skill in:

a) analysing and applying the following formulas for changes in time, length, and mass as the speed of light is approached ($v > 0.1c$):
   - $t = t_0(1 - v^2/c^2)^{-1/2}$ for time dilation, where t_0 is the time interval between two events as measured in a reference frame in which the events occur at the *same position* and t is the time interval as measured in a frame moving at speed v relative to the first frame;
   - $1 = 1_0(1 - v^2/c^2)^{1/2}$ for length contraction, where 1_0 is the length of an object at rest and 1 is its length as measured in a frame relative to which the object is moving at speed v; the contraction occurs only in the direction of motion;
   - $m = m_0(1 - v^2/c^2)^{-1/2}$ for mass increase, where m_0 is the mass of the object at rest and m is its mass as measured in a frame relative to which the object is moving with speed v (2a, 2b, 5d);

b) graphing values for mass, length, and time as functions of velocity (2b, 5d, 8b);
c) mathematically extending the effects for mass, length, and time as functions of velocity to other physical quantities such as volume and density (2b, 5d);
d) solving problems that involve the energy-mass relationship developed by Albert Einstein, $E = mc^2$ (5d).

Knowledge. Students will be expected to:

a) understand the following terms: frame of reference, relative motion, time dilation, length contraction, mass increase, rest mass;
b) describe and state the significance of the Michelson-Morley experiment (2a);
c) state the two postulates of Einstein's special theory of relativity (2a, 8a);
d) differentiate between the special theory of relativity and the general theory of relativity (2a, 8a);

---

*If two optional units are selected, they are to take ten hours each; if three are selected, they are to take about seven hours each.

e) describe some of Einstein's thought experiments (*Gedanken* experiments): simultaneity, time dilation, and the twin paradox (2a);
f) state the formulas for time dilation, length contraction, and mass increase as the speed of light is approached (2b, 8a);
g) state that matter and energy are equivalent and know the mathematical relationship between them.

2. Student Activities

Students are to:

a) discuss and report on (i) the Michelson-Morley experiment and state its significance; (ii) Einstein's two postulates of special relativity and their significance; and (iii) some of Einstein's thought experiments – simultaneity, time dilation, and the twin paradox (5a-5c, 8a);
*b) investigate mathematically the effects on a person's mass, length, time, volume, and density of travelling at 0.1, 0.5, and 0.9 of the speed of light and plot graphs for the first three of these over a range of speeds. Note that these effects would be measurable only by observers relative to whom the person was moving; there would be no change according to the actual person who is travelling (5d, 8b);
c) read an essay or a dissertation involving the theory of special relativity and then summarize the reading in report form (8c).

3. Applications

a) Authors of science fiction and books on space travel often try to take the special theory of relativity into consideration.
b) Atomic particles can be made to approach the speed of light, and the special theory of relativity must be taken into account in scientific work related to them.
c) Nuclear fusion and fission clearly demonstrate the equivalence of mass and energy.

4. Societal Implications

a) A knowledge of the ultimate speed limit of matter puts a lower limit on the time required for space travel.
b) The equivalence of mass and energy has placed a tremendous responsibility on governments to ensure that nuclear energy is utilized for beneficial rather than for destructive purposes.
c) The funding of scientific research requires knowledgeable co-operation among scientists, technologists, politicians, and the general public.

5. Evaluation of Student Achievement

At least 60 per cent of the term mark for this unit is to be based on students':

a) displayed understanding of the premises, postulates, and ramifications of the special theory of relativity;
b) written reports on Einstein's thought experiments;
c) reports, oral or written, on techniques used by famous scientists to gain information about motion;
d) solving of physics problems.

6. Safety Considerations

In this unit specific hazards are not readily apparent. Students should not attempt to travel at the speed of light!

7. Possible Extensions

Some students might:

a) write an account on how our lives would be affected if the speed of light – the ultimate speed – were 90 km/h (25 m/s);
b) give a mathematical development for the Michelson-Morley experiment;
c) write a report on the Galilean and Lorentz transformations, including the derivations of the length-contraction and time-dilation formulas;
d) write a report on the relativistic addition of velocities;
e) derive a formula relating energy and momentum, given the formulas for the relativistic energy and relativistic momentum of a mass travelling at a speed that approaches that of light;
f) study the principles and fundamentals of Einstein's general theory of relativity.

---

*See the subsection entitled "Student Activities" on page 5.

8. Some Teaching Suggestions

a) Introducing this unit with mathematical representations of the special theory of relativity should be avoided. Students are to be encouraged to discuss relativistic effects on time, length, and mass in order to extend their thinking about physical phenomena.
b) In activity 2b a computer can be used to generate the data and graphs based on the formulas related to time dilation, length contraction, and mass increase.
c) Selections for activity 2c might include the following:

- Barnett, Lincoln. *The Universe and Dr. Einstein*. Alexandra, Va: Time-Life, 1982.
- Gamow, George. *Mister Tompkins in Paperback*. New York: Cambridge University Press, 1967.
- ———. *One, Two, Three ... Infinity: Facts and Speculations of Science*. New York: Viking Press, 1961.
- Gardiner, Martin. *The Relativity Explosion*. New York: Random House Incorporated, 1976.

Optional Unit 2

Bodies in Equilibrium

*Time: 7 or 10 hours**

This unit helps to humanize the study of physics by treating the subject of equilibrium in relation to human bodies as well as to inanimate objects and materials. In addition to a consideration of the strength of materials, this study deals with ways in which the effects of physical stress on the body can be alleviated. For example, some people wear braces to align their teeth, athletes wear knee braces to prolong their careers, whiplash victims wear collars to support their heads, and doctors apply traction devices to broken legs.

This unit may be divided into topics such as the following:

- Torque
- Centre of gravity
- Conditions for equilibrium of a body
- Elasticity
- Stress and strain
- Young's modulus

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the fact that physical principles are used in correcting the alignment of various parts of the body (3d, 3f);
b) a healthy concern about maintaining physical fitness and practising proper back care to reduce physical stress to the human body (3f, 4b);

---

*If two optional units are selected, they are to take ten hours each; if three are selected, they are to take about seven hours each.

c) an appreciation of the fact that physics provides an understanding of the effects of stress and strain on materials and consequently leads to methods of improving their ultimate strength (3a, 3b, 3e, 4a, 4f);
d) an interest in career opportunities in physiotherapy, orthodonture, structural engineering, architecture, orthopedics, and the building trades, all of which require a knowledge of statics (4e).

Skills. Students will have the opportunity to develop skill in:

a) observing, measuring, and recording data, for example, when investigating Hooke's law, elastic limits, or forces in equilibrium (2);
b) plotting data and calculating a slope to determine, for example, Young's modulus (2c-2e);
c) drawing and analysing free-body force diagrams (2b);
d) experimenting to determine the elastic limit, the elastic modulus (Young's modulus), and the ultimate strength of a material (2d, 2e, 6);
e) solving problems that involve the following formulas:

   - torque (or moments), $T = rF$;
   - conditions for static equilibrium, $\Sigma F = 0, \Sigma T = 0$;
   - stress and strain, $\sigma = F/A$ and $\epsilon = \Delta L/L$;
   - ultimate tensile strength, $\sigma_T =$ maximum stress;
   - elastic modulus (Young's modulus), $E = \sigma/\epsilon$ (5c).

   Note that such problems are to include concepts related to simple machines; support structures such as beams, cables, and arches; traction devices used in physical therapy; and muscles and joints that exert forces on the arms, legs, back, head, and jaw (5b).

Knowledge. Students will be expected to:

a) identify torque (or moment) as $T = rF$ where the radius of the torque is perpendicular to the force (2b);
b) describe how to locate the centre of gravity (centre of mass) of a body (2a);
c) distinguish between stable, unstable, and neutral equilibrium;
d) specify the conditions for static equilibrium (2b);
e) understand that, when the sum of the torques equals zero for a body in equilibrium, this will be true no matter where the pivot point is taken in the plane of the forces (2b);
f) identify statics as the study of forces acting on an object that is in static equilibrium and distinguish between static and dynamic equilibrium (2b);
g) state Hooke's law and the meaning of the terms *elastic region* and *elastic limit* (2c, 2d);
h) define *stress* and *strain* and apply the relationship between them in the form of the elastic modulus (Young's modulus), that is, $E = \alpha/\epsilon = (F/A)/(\Delta L/L) =$ stress/strain (2e);
i) describe the three types of stress: tension, compression, and shear (2e, 8d);
j) use tables of values of ultimate tensile strength and Young's modulus for some metals, masonry materials, fibres, bone, and tendons to solve problems (2d, 2e, 5c, 8b);
k) list various careers that involve work on bodies in equilibrium (4e, 8e).

2. Student Activities

Students are to:

a) locate the centre of gravity of various geometric plates;
*b) experimentally demonstrate the two conditions for equilibrium, $\Sigma F = 0$ and $\Sigma T = 0$, using at least three non-parallel forces, and show the related calculations (8a, 8c);
c) verify Hooke's law by experimenting with a variety of materials that are different from any that were used in core unit 3 (6a, 6b);
d) determine the elastic limit of a material (6);
*e) determine Young's modulus of a material (6a, 6b, 8d).

3. Applications

a) The design of bridges, walkways, vehicles, and buildings must take into account torques, stability, balance, and forces in equilibrium.
b) Elasticity is important in apparently rigid structures such as tall buildings, ships, bridges, and bones so that there can be some give to large applied forces.
c) Stability and balance play an important role in athletics; dancing; acrobatics; the lifting of heavy loads; the design of trains, trucks, ships, and planes; and the building of cranes (e.g., the distance between railway tracks affects the stability of a train).
d) Stress and strain apply to physical therapy, the provision of traction for injured body parts, exercising, athletics, and the use of athletic equipment.
e) Arches, domes, bridges, steel skeletons of buildings, metal presses, car frames, and human and animal skeletons can tolerate some stress, but care needs to be taken to understand ultimate strengths and safety allowances in order to prevent accidents in both static and dynamic situations.
f) Body alignment can be improved and stress reduced by the use of devices that exert forces on various parts of the body (e.g., teeth braces, neck collars, traction apparatuses, knee braces, plaster casts, contoured chairs, firm mattresses).

---

*See the subsection entitled "Student Activities" on page 5.

4. Societal Implications

a) The production of safer cars and the construction of safe buildings have resulted from studies of the ultimate strengths of terials. When inadequate attention has been given to the physics of structural analysis, serious accidents can occur.
b) Poor posture and the incorrect lifting of heavy objects can cause undue physical stress or injury.
c) The circus provides entertainment in the application of balance and stability where equilibrium must be maintained (e.g., tightrope walking and balancing acts).
d) The wheels of cars must be aligned and balanced to ensure safety on highways and to prevent unnecessary wear and tear on tires and other parts.
e) Careers that involve work in which static forces, equilibrium, and elasticity play important roles include the following: architect, athlete, dancer, acrobat, designer and repairer of vehicles and machinery, therapist, orthodontist, engineer, carpenter, builder, crane operator, scientist.
f) The safety of people often depends on a knowledge of the strength of materials and the application of the principles of physics (e.g., ski-lift and elevator cables, transportation systems, steel frameworks in buildings and bridges, scaffolding, roofing in homes and cottages, harnesses for parachutists and skydivers).

5. Evaluation of Student Achievement

At least 40 per cent of the term mark for this unit is to be based on students':

a) laboratory experiments and reports;
b) demonstrated understanding of the applications of statics to the human body (8b);
c) solving of physics problems (8a, 8c).

6. Safety Considerations

a) In experiments involving large forces, care must be exercised to ensure that the procedure is safe.
b) When the elastic limit of a material is tested, special care must be taken to prevent injury or damage in case the material fractures.

7. Possible Extensions

Some students might:

a) discover that the torque of a couple is independent of the selected pivot point;
b) study the vector nature of a torque;
c) summarize information on shear modulus and bulk modulus;
d) study examples of physical therapies for the human body (e.g., for back injuries);
e) build a model bridge and then calculate and test its ultimate strength;
f) determine the actual and ideal mechanical advantage and the efficiency of some simple machines.

8. Some Teaching Suggestions

a) Problems should be restricted to coplanar forces. Three-dimensional problems should be used only as a possible extension for very capable students.
b) The human body can be used to illustrate many of the concepts involved in this unit. Such use, however, should be well within safe limits.
c) Some of the assigned numerical problems should reflect actual situations in which students measure the magnitudes and indicate the directions of the forces acting on an object in the classroom.
d) Students should be supplied with a good table of data on the ultimate tensile strength and the elastic modulus or Young's modulus of some metals, building materials, fibres, bone, and tendon.
e) A guest speaker (e.g., an architect, a building inspector, or a therapist) could enrich this unit.

Optional Unit 3

Electromagnetic Radiation

*Time: 7 or 10 hours**

The culmination of electromagnetic theory in the nineteenth century was the prediction, and subsequent experimental verification, that various forms of radiation must consist of waves of electromagnetic fields that travel through space. This great discovery established the electromagnetic character of light and provided a framework for discoveries of high-energy radiation. Life in the twentieth century, with radio, television, and satellite communication, has been profoundly influenced by the technology based on these findings. In this unit students study the properties of the various components of the electromagnetic spectrum. Familiar applications can then be related to the distinguishing properties of each type.

This unit may be divided into topics such as the following:

- ▸ Properties of electromagnetic radiation
- ▸ The electromagnetic spectrum
- ▸ AM and FM communication
- ▸ Black-body radiation
- ▸ The greenhouse effect

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the fact that theoretical physics may lead to predictions that are verifiable by experiment;
b) a sense of satisfaction in the realization that there is aesthetic as well as intellectual pleasure in the development of a theory that unifies two apparently unrelated areas of science.

Skills. Students will have the opportunity to develop skill in:

a) using measuring devices such as a microwave detector to illustrate the reflection, polarization, and interference of microwaves; a thermopile to illustrate the temperature effect of infrared radiation when it is absorbed by an object; and a Geiger counter to measure the intensity of gamma radiation (2a, 2b, 2d);
b) observing physical phenomena such as fluorescence under ultraviolet light, the ionization effects of gamma rays, and the results of X-ray photography (2b, 2c);
c) designing experiments that verify the inverse square law for gamma rays and determine the absorption constant (attenuation coefficient) of an absorber of gamma rays (2d);
d) solving problems using $c = f\lambda$ (5d).

Knowledge. Students will be expected to:

a) outline the historical prediction and subsequent detection of electromagnetic radiation (2e);
b) know that electromagnetic waves are produced by an accelerated charge (8b);
c) list the regions of the electromagnetic spectrum in order of decreasing wavelength;
d) describe sources and properties of the various types of electromagnetic radiation, their beneficial and harmful effects, and some applications of each type (8b);
e) explain, with the aid of a diagram, the operation of an X-ray tube;
f) identify the components of a communications channel to provide for the generation, transmission, modulation, amplification, detection, tuning, and demodulation or detection of a signal;
g) distinguish between amplitude modulation (AM) and frequency modulation (FM);
h) describe the operation of a simple tuning circuit;
i) sketch curves to illustrate the spectrum of frequencies emitted by a black body at different temperatures;
j) describe the greenhouse effect;
k) list some career opportunities related to electromagnetic radiation (2e, 5b, 8c).

2. Student Activities

Students are to:

*a) observe the reflection, polarization, and interference effects of microwaves *or* measure the wavelength of microwaves (8a);
*b) detect infrared radiation using a thermopile or Crooke's radiometer *or* observe the fluorescence of minerals or other materials that are illuminated with ultraviolet light (6a, 8a);

---

*If two optional units are selected, they are to take ten hours each; if three are selected, they are to take about seven hours each.

*See the subsection entitled "Student Activities" on page 5.

c) observe and explain the discharge of an electroscope by gamma rays (8a);
*d) determine the absorption constant for lead (or another material) using gamma rays *or* verify the inverse square law for gamma rays (6b, 8a);
*e) read about and report on some aspect of historical development, contemporary application, or career opportunity related to electromagnetic radiation (5b, 5c, 8b, 8c).

3. Applications

a) Television and telephone information can be transmitted by microwave relay towers or by geosynchronous satellites.
b) Ships and aircraft navigate by means of radar.
c) Radio telescopes receive radio waves from outer space.
d) Satellites, space probes, and guided missiles are controlled by radio waves.
e) Infrared radiation is used for remote sensing and thermography.
f) Ultraviolet radiation can be used to kill bacteria.
g) X rays are used for diagnosis and therapy in medicine and for non-destructive testing in industry.
h) Gamma rays are used in the treatment of cancer.
i) Microwaves are used in cooking.

4. Societal Implications

a) Advances in communications technology provide television viewers with a wide choice of programming but can pose a potential threat to the Canadian identity.
b) Remote sensing is used to detect military installations and thus is a means of helping to enforce arms-control agreements.
c) "The greenhouse effect" refers to our contaminated atmosphere, which can allow the entry of solar visible radiation while trapping the subsequent infrared radiation emitted by the earth.
d) Our health and general well-being is influenced by various forms of radiation (e.g., sunshine is enjoyable and within limits is beneficial, with the ultraviolet rays providing a suntan, which for some people may be harmful; X rays are used in a diagnostic role; gamma or X rays are used in cancer therapy; and bacteria and viruses can be destroyed or deactivated by radiation, which can therefore be used to sterilize medical supplies and equipment and packaged food as well).

5. Evaluation of Student Achievement

At least 40 per cent of the term mark for this unit is to be based on students':

a) laboratory experiments and reports;
b) scientific explanations of electromagnetic phenomena;
c) reports on some historical discovery, a contemporary application, or a career possibility related to electromagnetic radiation;
d) problem solving.

6. Safety Considerations

a) Students should be warned not to view intense light or ultraviolet radiation directly with the naked eye.
b) Appropriate procedures should be developed for handling lead.

7. Possible Extensions

Some students might:

a) report on equipment or techniques used in contemporary astronomy (e.g., radio telescopes, optical telescopes, X-ray detectors, the Doppler effect);
b) investigate the use of microwaves in cooking.

8. Some Teaching Suggestions

a) Students should be provided with opportunities personally to detect various types of electromagnetic radiation and to observe their properties.
b) Students should be encouraged to do some independent reading and study, in science magazines and other convenient sources, on topics related to electromagnetic radiation.
c) Students can be asked to determine whether each of the following is likely to be engaged in work related to electromagnetic radiation. This exercise would expose students to thinking about a wide range of career opportunities in science.

- aerospace engineer
- air-traffic controller
- airplane pilot
- astronomer
- astrophysicist
- atomic/molecular physicist
- audio engineer
- electronic engineer
- engineering physicist
- forensic scientist
- hydrographic surveyor
- radio-communications officer
- laboratory technologist
- metallurgical engineer
- meteorologist
- nuclear physicist
- oceanographer
- ophthalmologist
- technician
- radiologist
- radiotherapist
- X-ray technologist

---

*See the subsection entitled "Student Activities" on page 5.

Optional Unit 4

Elementary Particles

*Time: 7 or 10 hours**

The study of elementary particles continues to have a high profile and provides a source for student interest and motivation. The purpose of this unit is to introduce students to research methodologies in particle physics; to provide insight into the theories proposed to explain the behaviour and existence of such particles; and to emphasize that particle physics is a relatively new area that will continue to expand, to alter previous conceptions of matter, and to lead people into activities and careers that are yet to be discovered.

This unit may be divided into topics such as the following:

- The structure and composition of the atom
- Review of radioactive decay
- Conservation laws and their application
- Particles and their antiparticles
- Particle accelerators and detectors
- Fundamental forces of nature
- The exclusion principle
- Classification of elementary particles
- Quarks and antiquarks

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the fact that the search for elementary particles is ongoing and that the particles now considered elementary may be shown to be composite at some future date (2b, 4a, 4b);
b) a concern for the need to support research into elementary particles, not only because such research increases the knowledge of humanity, but also because it might have spinoffs that are of material benefit to humanity (3b, 4b);
c) an interest in possible career opportunities related to elementary particles (4a).

Skills. Students will have the opportunity to develop skill in:

a) searching for information, for example, when reading about the characteristics of elementary particles (2b, 5);
b) observing, for example, when tracing electron paths in a cloud chamber or a cathode-ray tube (2a, 6);
c) identifying, for example, when naming different kinds of particles from photographs of tracks made in an accelerator (2a);
d) classifying, for example, when categorizing certain elementary particles as hadrons or leptons (2a).

Knowledge. Students will be expected to:

a) describe and explain how some particle accelerators and detectors operate (5);
b) distinguish between elementary and composite particles (2a);
c) list a substantial number of presently known elementary particles, such as electrons, neutrinos, muons, and quarks (2a);
d) state some of the characteristics of elementary particles, such as their mass and charge;
e) state the conservation laws that apply to elementary-particle interactions (8b);
f) identify the four kinds of fundamental forces in nature and list them in order of decreasing strength.

2. Student Activities

Students are to:

a) study photographs of paths formed by a variety of elementary particles;
*b) read about and report on a topic related to elementary particles (5).

3. Applications

a) Mesons are occasionally used in cancer therapy.
b) Cyclotrons are used in some hospitals to produce particles with half-lives of a few minutes. Such particles are used in various forms of treatment.
c) Accelerators can produce X rays and strong beams of photons; these can be used in diagnostic and therapy work.

---

*If two optional units are selected, they are to take ten hours each; if three are selected, they are to take about seven hours each.

*See the subsection entitled "Student Activities" on page 5.

4. Societal Implications

a) Work involving investigations in particle physics provides careers for many scientists and technologists.
b) Projects involving particle physics often become large-scale efforts requiring large budgets. One solution to this problem has been the implementation of international enterprises, for example, CERN (European Council for Nuclear Research) in Switzerland.

5. Evaluation of Student Achievement

At least 40 per cent of the term mark for this unit is to be based on students' written or oral reports on some topic related to elementary particles.

6. Safety Considerations

If cathode-ray tubes or radioactive sources are used, students are to be aware of safety precautions and shielding techniques against high voltage and radiation hazards.

7. Possible Extensions

This unit can be extended for capable students by providing opportunities for them to read about elementary particles in greater depth than is normally required. They can expand their knowledge by learning about particles beyond those usually prescribed for the course.

8. Some Teaching Suggestions

a) Students should be encouraged to read and study about selected aspects of particle physics on their own. Developing a formal report as an assignment should help prepare students for possible further studies at the postsecondary level.
b) This unit can be used to bring together many physical principles that have been studied in earlier units and courses (e.g., conservation laws; wave-particle duality; forces in electric, gravitational, and nuclear fields).
c) This unit should include the contributions of a number of scientists to particle physics. References to the lives of these people should indicate the nature of the human endeavour, which is the essence of science.

Optional Unit 5

Locally Designed Unit

*Time: 7 or 10 hours**

This unit is the same for the physics OAC as optional unit 4, "Locally Designed Unit", is for the Grade 12 advanced-level physics course. A different set of topics from those selected in the previous grade should, of course, be selected for this unit.

---

*If two optional units are selected, they are to take ten hours each; if three are selected, they are to take about seven hours each.

Appendixes

Appendixes

A. Science Courses and Their Course Codes

B. The Table of Contents of Part 1

Appendix A

Science Courses and Their Course Codes

The secondary school guideline courses in science authorized under this document have the following course codes:

Science, Grade 9, Basic Level	SNC1B
Science, Grade 9, General Level	SNC1G
Science, Grade 9, Advanced Level	SNC1A
Science, Grade 10, Basic Level	SNC2B
Environmental Science, Grade 10, General Level	SEN2G
Science, Grade 10, General Level	SNC2G
Environmental Science, Grade 10, Advanced Level	SEN2A
Science, Grade 10, Advanced Level	SNC2A
Science, Grade 11, Basic Level	SNC3B
Applied Biology, Grade 11, General Level	SBA3G
Applied Chemistry, Grade 11, General Level	SCA3G
Environmental Science, Grade 11, General Level	SEN3G
Biology, Grade 11, Advanced Level	SBI3A
Chemistry, Grade 11, Advanced Level	SCH3A
Science, Grade 12, Basic Level	SNC4B
Environmental Science, Grade 12, General Level	SEN4G
Geology, Grade 12, General Level	SGE4G
Applied Physics, Grade 12, General Level	SPA4G
Environmental Science, Grade 12, Advanced Level	SEN4A
Geology, Grade 12, Advanced Level	SGE4A
Physics, Grade 12, Advanced Level	SPH4A
Technological Science, Grade 12, General Level	STE4G
Biology, OAC	SBI0A
Chemistry, OAC	SCH0A
Physics, OAC	SPH0A
Science in Society, OAC	SSO0A

The following general rules govern science course codes:

- All science course codes begin with an **S**.
- **SNC** identifies a course that has only the name "Science".
- Where one word other than "Science" describes the course, the first two letters of that word follow the **S** (e.g., **SBI** means "Science, Biology" or simply "Biology"; **SEN** means "Science, Environmental" or "Environmental Science").
- Where two words other than "Science" describe the course, the initial letters of those words are used (e.g., **SCA** means "Science, Chemistry Applied" or simply "Applied Chemistry").
- The fourth character in the course code, **1**, **2**, **3**, **4**, or **0**, represents Grade 9, 10, 11, 12, or an OAC respectively.
- The fifth character represents the level of difficulty: **B** for basic, **G** for general, or **A** for advanced.

For further information on course codes, refer to the *Manual for the Common Course Code* (Toronto: Ministry of Education, Ontario, 1986).

Appendix B

The Table of Contents of Part 1

Preface
Introduction
  The Parts of the Guideline
  Guideline Courses
  Superseded Guidelines

A. Goals and Aims

1. The Value and Purpose of Science Education
2. The Goals of Education and the Role of Science
3. The Aims of the Science Curriculum
   - 3.1 The Aims
   - 3.2 The Nature of Science
   - 3.3 Scientific Literacy
   - 3.4 Curriculum Emphases – Blending Curriculum Aims With Content

B. Science Program Framework

4. Science Courses
   - 4.1 The Science Continuum From Kindergarten to OACs
   - 4.2 Levels of Difficulty: Basic, General, and Advanced
   - 4.3 Science Courses and Credits
   - 4.4 Units of Study Within Each Course
   - 4.5 Recommendations Regarding Course Selections
5. Teaching Policy
   - 5.1 Content and Process
   - 5.2 Components in Each Unit of Study
   - 5.3 Teaching Policy for All Science Units
   - 5.4 Time Allocations for Each Unit
   - 5.5 Locally Designed Units
   - 5.6 The Grade Placement and Naming of Local Science Courses
   - 5.7 Overall Policy for Science Courses

C. Special Features of the Science Program

6. Considering the Science Student
   - 6.1 The Image of the Successful Science Student
   - 6.2 Program Adaptations for Exceptional Students
   - 6.3 Individualized Instruction
   - 6.4 Life-Management Skills
   - 6.5 Employment Awareness
   - 6.6 Sex Equity
   - 6.7 Multiculturalism
7. Language and Science
   - 7.1 Language Skills
   - 7.2 Assignments and Evaluation
   - 7.3 English Vocabulary in French-Immersion Science Courses
   - 7.4 Immigrant Students
8. Measurement
   - 8.1 Estimation
   - 8.2 Metric Units and Physical Quantities
   - 8.3 Accuracy and Precision
   - 8.4 Formats in Solutions to Problems
9. Safety
   - 9.1 Safety in the Laboratory
   - 9.2 Some Recommended Safety Procedures
   - 9.3 Animal Care in Science Courses
   - 9.4 The Safe Use of Plants

10. Values in Science Education
    10.1 The Role of Values Issues in Science Courses
    10.2 Handling Sensitive Issues

D. Implementation

11. Curriculum Planning and Staff Development
    11.1 Policy Planning at the Board Level
    11.2 Program Planning at the School Level
    11.3 Course Planning at the Teacher Level
    11.4 School-Board Curriculum Documents
    11.5 Staff Development
12. Resources
    12.1 Science Laboratories and Equipment
    12.2 Library Resource Centres
    12.3 Textbooks and Learning Materials
    12.4 Calculators
    12.5 Computers
    12.6 The Scientific Community
13. Modes of Delivery
    13.1 Bilevel and Multigrade Classes
    13.2 Co-operative Education
    13.3 Program Packages
    13.4 Adult Education
    13.5 Independent Learning Centre
    13.6 Specialized Schools
14. Evaluation
    14.1 Evaluating Guideline-Implementation Progress
    14.2 Evaluating Student Achievement
    14.3 Self-Evaluation of Teacher Performance
    14.4 Evaluation of Program Effectiveness

Appendixes

A. Science Courses and Their Course Codes
B. Physical Quantities
C. Metric Editorial Practice
D. Some Poisonous Plants
E. Some OAIP Instrument Types and Learning Domains

88-063
© Queen's Printer for Ontario, 1988

ISBN 0-7729-2418-X